Cunninghamia

A journal of plant ecology for eastern Australia



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Cunninghamia

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Allan Cunningham, botanist and explorer (1791–1839)

Cover: Black and white 1905 photograph of Captain Cook's monument at the Botany Bay landing place, Kurnell, showing native low scrub and *Banksia integrifolia*, interposed with corresponding 2006 view (colour) showing subsequent predominance of planted *Araucaria* trees.
See Benson and Eldershaw Backdrop to encounter: *the 1770 landscape of Botany Bay, the plants collected by Banks and Solander and rehabilitation of natural vegetation at Kurnell.*
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Treeless vegetation of the Australian Alps

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Abstract: Based on 1222 floristic quadrat samples, 56 plant communities were identified in treeless vegetation in the Australian Alps of south-eastern Australia. (c. 35° 30′–38°S, 146°–149°E). The study encompassed vegetation from above the upper limit of trees on mountain tops (i.e. the truly alpine environment) and below the inverted treeline in subalpine valleys. Generally, grasslands develop on deep humus soils, heathlands occur on shallower or rocky soils, and wetland communities are found in places of permanent or intermittent wetness. Duration of snow cover, lithology, altitude and exposure are also important determinants of the spatial arrangement of communities. Broadly, communities within a geographic region are more closely related to each other than to communities of similar structure or dominants from other geographic areas. Many communities are either very localised or are widespread with a small area of occupancy. Fourteen communities are probably eligible for listing as threatened, either alone or as aggregates with associated communities.

A total of 710 native taxa from 82 families has been recorded. There is a high level of endemism – 30% of taxa are ± restricted to treeless vegetation in the Australia Alps and a further 14% are ± restricted to treeless vegetation but occur in mountain areas outside the Australian mainland (e.g. Tasmania and New Zealand). Thirteen taxa are listed in the *Environment Protection and Biodiversity Conservation Act 1999* as threatened and a further 18 taxa are identified that may be eligible for listing as threatened nationally. 131 non-native taxa have been recorded in natural vegetation.

Treeless vegetation has been intensively utilised since European settlement, initially as summer pastures for cattle and sheep but more recently as water catchments for electricity production and as tourist attractions both in winter and summer. Many communities are slowly recovering from past pressures and from the fires of 2003, which burnt most of the area for the first time since 1939. The treeless vegetation of the Australian Alps faces an uncertain future because of increased pressure from tourism and the unknown impacts of global warming.

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Introduction

The Australian Alps can be loosely defined as the mountains and plateaux of the Great Dividing Range and surrounds that receive persistent winter snowfall. In this sense, the Alps extend from Lake Mountain in Victoria to Namadgi National Park in the Australian Capital Territory, and include the highest summits of mainland Australia (c. 35° 30′–38°S, 146°–149°E). A feature of the Australian Alps is the absence of trees on many mountain tops at the highest elevations and in some lower valleys and plains.

The treeless vegetation of the Australian Alps is floristically outstanding – almost 60% of taxa in some parts are restricted to high mountain areas (McDougall 1997). The distinctness of the flora has long attracted botanical interest. Noted botanists and naturalists such as Baron Ferdinand von Mueller, Richard Helms, Joseph Maiden, James Stirling and Alfred Tadgell had made numerous collections of the high mountain flora by the early 20th Century, well in advance of many other ecosystems of south-eastern Australia (Willis 1989, Gillbank 1990, Willis & Cohn 1993, Costin et al. 2000). The treeless vegetation of the Australian Alps also has a long history of ecological studies on plant–disturbance interactions (e.g. Carr & Turner 1959b, Wimbush & Costin 1979, Williams & Ashton 1987), and possesses some of the longest running ecological monitoring experiments in Australia (e.g. Wahren et al. 1994, Scherrer 2004). Treeless communities in the Alps were the subject of some of the earliest community classification in Australia (e.g. Costin 1954, McVean 1969, McDougall 1982, Walsh et al. 1984, Helman & Gilmour 1985) and large-scale vegetation mapping based on such classifications (Victoria Conservation Trust 1982–85, Walsh et al. 1984).

Despite the level of botanical interest and the various floristic classifications produced, a single classification of treeless vegetation in the Australian Alps has been hamstrung by State boundaries and regional differences in classification systems. Kirkpatrick (1989) attempted to synthesise available data (including that from Tasmania) but did not have floristic data from most treeless areas in Kosciuszko National Park, and some data were missing from Victorian data sets. Keith (2004) provided a synopsis of alpine and subalpine communities in New South Wales and the Australian Capital Territory but that work was very broad-scale. In this paper we present a classification of treeless vegetation of the Australian Alps, based on available data from Victoria (McDougall 1982,

Walsh et al. 1984), the Australian Capital Territory (Gilmour et al. 1987, Helman et al. 1988), New South Wales (Ecology Australia 2003), and 361 new floristic quadrats sampled by us in and around Kosciuszko National Park.

Study area

The study area was defined by the extent of treeless vegetation in the high mountains of south-eastern Australia. It extends from Lake Mountain in Victoria to Namadgi National Park in the Australian Capital Territory (Fig. 1), a distance of about 350 km, and ranges in elevation from about 1000 m on Mt Whitelaw (Baw Baw National Park) to 2229 m on Mt Kosciuszko (Kosciuszko National Park). Based on available vegetation mapping, there are about 160,000 ha of treeless vegetation in the Australian Alps, c. 70,000 ha in Victoria (McDougall 1982, Walsh et al. 1984, Mueck and McCormick 2002) and c. 90,000 ha in NSW and the ACT (Thomas et al. 2000).

The study encompasses vegetation from above the upper limit of trees on mountain tops (i.e. the truly alpine environment) and below the inverted treeline in subalpine valleys. Generally, the elevation of treelines increases with decreasing latitude, and so, for example, the upper treeline at Mt Howitt in Victoria (latitude 37° 10') is about 1600 m a.s.l. whilst the upper treeline at Mt Jagungal in NSW (36° 08') is about 1900 m a.s.l. Alpine vegetation is effectively absent from the ACT, which has a maximum elevation of 1911 m on Mt Bimberi. In many places, the upper treeline is continuous with the lower treeline. The lower elevational boundary of treeless vegetation is often indistinct, extending in narrow strips down valleys and onto isolated rocky outcrops. No attempt was made to constrain the study area altitudinally. However, the majority of samples are from the larger patches of treeless vegetation rather than linear valley strips. Naturally treeless vegetation also occurs to the east of the Great Dividing Range in NSW, on the Monaro and coastal escarpment. Whilst some of this may have floristic affinities to the vegetation described in this paper and be treeless for similar ecological reasons, no survey was done by us outside the Australian Alps and available data from these areas were not used.

Most treeless vegetation is within National Park, although small portions are in other tenures, including privately owned land. Ski resorts in NSW are within Kosciuszko National Park while in Victoria, six of the skiing areas are within specially designated alpine resorts surrounded by the Alpine and Baw Baw National Parks. The Mt Buffalo skifields are incorporated into the Mt Buffalo National Park.

Environmental determinants

The Australian Alps are a series of elevated plateaux, ridges and isolated mountain tops of uncertain origin (Ollier 1987). Much of the Alps lie along the Great Dividing Range, which separates the Murray and coastal watersheds, but there are numerous peaks and landforms such as Mt Bogong, Mt Buffalo, Mt Baw Baw and all of the mountains of the Australian Capital Territory that are offset. The Alps are characterised by low temperature. Sub-zero temperatures of the past have helped shape the landscape (through localised glaciation and the fracturing of rock) and continue to influence the patterns of vegetation today (e.g. by limiting tree establishment and thus creating treelines). Glaciation in the last Ice Age was confined to a small area in the vicinity of Mt Kosciuszko, although periglacial forces were responsible for many of the notable rock features elsewhere, such as block streams (Peterson 1971). The Australian Alps are geologically diverse (Ollier & Wyborn 1989). The Kosciuszko Main Range area is predominantly granitic whereas much of the Bogong High Plains in Victoria are underlain with metamorphic material (gneiss and schist). Limestone, basalt, other igneous and various sedimentary rocks are locally exposed. Soils tend to be highly organic and acidic.

The topography of the Australian Alps – often a combination of steep slopes and broad, flat valleys – has a profound effect on local weather conditions. When coupled with spatial variation in drainage, soil depth and rock type, it is not surprising that the corresponding vegetation patterns are extremely complex. Some of the major factors influencing patterns of vegetation are described below.

Frost. Sub-zero temperatures may occur at any time of the year and are common during plant growing seasons. Frost may also be localised. Cold air tends to accumulate in valleys at night producing a large differential in air temperature between valley bottom and ridge top (Williams 1987). In such situations, plants growing in valleys encounter more frosts than those growing upslope. The relative tolerance of high mountain plants to a high frequency of frost is unknown but it is clear that snow gums (*Eucalyptus pauciflora* sens. lat.) and some shrubs are intolerant, at least in their juvenile stages. It is this that creates the inverted treelines in the Australian Alps, with the trees and tall, closed heathland on the upper slopes and ridges and the grasslands and low heaths occurring in the valley bottoms, the opposite of the pattern on the high peaks (Harwood 1980, Slatyer 1989). Frost is also probably responsible for inhibiting the establishment of the many non-native species that are inadvertently brought to the Alps (Mallen-Cooper 1990). The development of needle ice in moist, bare soils (Fig. 2) limits the establishment of many alpine species and may influence the balance between shrubs and herbs in some plant communities (Williams 1992).

Snow. Snow in itself has little bearing on mountain plants. Differences in the duration of snow cover, however, have a profound effect on plant distribution and vegetation pattern. At the lowest elevations, a persistent cover of snow is rare, and plants experience much longer periods of frost exposure in winter than those at higher elevations. Many of the species from these lower elevation areas also occur

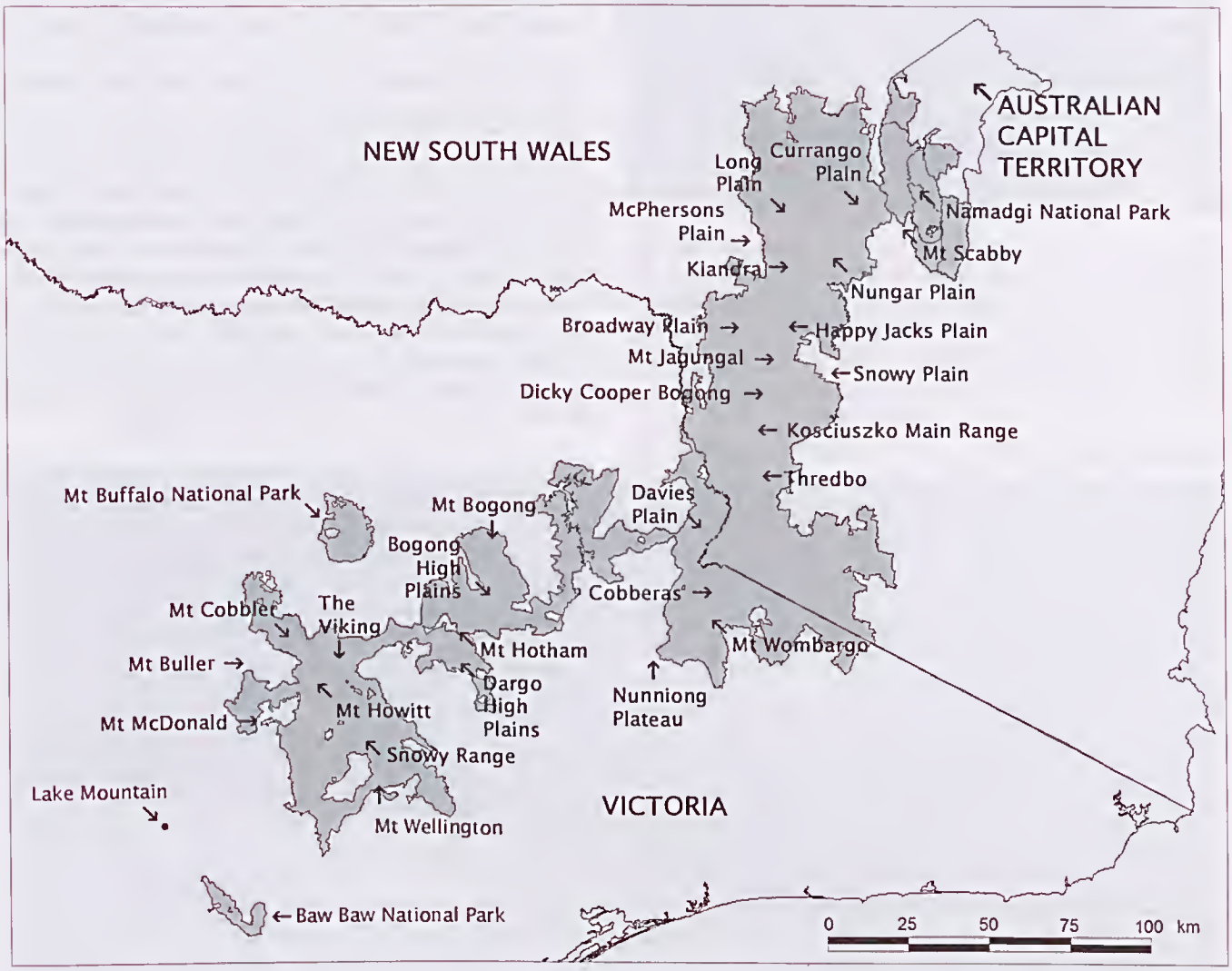


Fig. 1. Key sites mentioned in the text: Lake Mountain; Baw Baw National Park (includes Erica, Mt Whitelaw), Mt McDonald (The Bluff), Mt Buller (Mt Stirling), Mt Cobbler, Mt Wellington (Bennison Plains), Mt Howitt (Crosscut Saw, Howitt Plains, Mt Speculation), Snowy Range, The Viking, Mt Buffalo National Park (Hospice Plain, Mt Buffalo), Bogong High Plains (Basalt Hill, Cope Creek, Falls Creek, Mt Cope, Mt Fainter, Mt Feathertop, Mt Jim, Mt McKay, Mt Nelse, Pretty Valley, Spion Kopje), Mt Bogong, Dargo High Plains (Gow Plain, Lankeys Plain), Mt Hotham (Dinner Plain, Mt Loch), Davies Plain, Cobberas (Mt Cobberas), Nunniong Plateau (Brumby Point), Koseiuszko Main Range (Blue Lake, Charlottes Pass, Carruthers Peak, Guthega, Guthrie Creek, Hedley Tarn, Lake Albina, Mt Blue Cow, Mt Koseiuszko, Mt Lee, Mt Townsend, Mt Twynam, Perisher, Ramshead Range, Rawsons Pass, Speneers Creek, Upper Snowy River), Mt Wombargo, Thredbo (Dead Horse Gap), Snowy Plain (Botherum Plain), Mt Jagungal (Bogong Plain), Broadway Plain (Emu Plain, Ogilvies Creek, Pretty Plain, Toolong Plain), Currango Plain (Blue Waterholes, Cave Creek, Cooleman Plain, Seventeen Flat), Kiandra (Mt Selwyn, Yarrangobilly Caves), McPhersons Plain (Sparkes Plain, Tomneys Plain), Long Plain, Nungar Plain (Boggy Plain, Gulf Plain, Tantangara Dam), Mt Scabby (Mt Kelly, Mt Murray, Scabby Ranges), Namadgi National Park (Grassy Creek, Mt Bimberi, Mt Gingera, Sheep Station Creek), Dicky Cooper Bogong (Munyang Creek), Happy Jacks Plain. The shaded area is National Park tenure.

at the highest elevations so it seems likely that they are not reliant on snow cover. At higher elevations, however, snow tends to aeeumulate in drifts on south and east facing slopes, blown there by the prevailing west to north-west winds and proteeted from melting in spring by the reduced solar irradiation of those aspeets. On the Kosciuszko Main Range and the Bogong High Plains, snow in these sites commonly endures until mid-summer. These snowpatches have produeed a distinct array of plant eommunities and eontain several speeies confined to this environment, which is characterised by a shortened growing season, abundant water while the snow is melting, and dry conditions once snow has melted.

Wind. The high ridges and summits of the Australian Alps are often subjected to strong wind, whieh eomes predominantly from a westerly direetion. The effect of this can be seen in wind-pruned trees and shrubs and the sorting of gravel and fines on the eastern side of bare patches of soil. On exposed ridges of shattered sedimentary roek, where the snow is commonly blown off into snowpatches, an open dwarf heathland forms. This community is best developed in the Kosciuszko area (where it is ealled windswept feldmark) but vegetation of similar structure and plant form ean be found in the highest mountains of Vietoria. The dominant shrubs of this community are pruned by the wind on their windward side and layer on the proteeted leeward side, gradually moving across the ridge at a rate ealculated to be about 1 em / year (Barrow et al. 1968).

Water. The perenniality of a water supply is a major determinant of plant distribution in the Australian Alps. Apart from the direct supply from rain, water may eome from springs, snowmelt or from eapillary movement of water aeross absorbent peaty substrates. Some springs are perennial but others dry during summer or autumn, the timing perhaps depending on rainfall and snow cover in previous years. All soils are sodden at the time of snowmelt but most dry quickly after. Within a given area, snow melts at different rates depending on snow depth, altitude and aspeet. That deposited on lee slopes of the highest mountains may provide a supply of water to plants at the base of the snow paek well into summer. All of these faetors mean that the treeless country is a mosaic of wet and dry habitats (and everything between). Many plants and eommunities have a specific hydrological niche. Patch death of plants has been observed in times of drought (Wimbush and Costin 1979). The long-term impact of periodie drought is, however, unclear.

Geomorphology. Although landforms of the treeless high country are a fundamental determinant of vegetation (through their effect on snow longevity, protection from wind and availability of water), two landforms peculiar to the high country eontain specific plant communities. 1) Sub-zero temperature and water have combined over long periods to shatter roek, which has aecumulated in streams on slopes or in piles at the base of outcrops. These bloek streams and boulder fields are common in areas with basaltic or granitie rock. They support a low, elosed heathland dominated by *Podocarpus lawreucei*, which is the primary habitat of the Mountain Pygmy Possum (*Burramys parvus*). 2) On some slopes of low gradient, the soil appears to have 'stretched', creating linear depressions of up to 30 cm depth. The cause of these features (called contour trenches by McElroy (1952)) is unelear. However, they fill with water periodically, following snow melt and heavy rain, and contain a distinetive flora, different to the adjoining vegetation only centimetres away.

Geology. The differences in flora and vegetation between different substrata are often subtle and there appear to be few species completely restricted to a single rock type. Geology does influence soil composition, however, thus indirectly determining species distribution in some cases. Limestone-derived soils are less acidic and basalt-derived soils are more fertile than typical alpine humus soils (Rowe 1972). For these reasons, weed diversity and abundance are usually greater in areas underlain by basalt and limestone. In grasslands of basalt areas, the dominant *Poa* speeies often appear to have more vigorous growth and forbs are less abundant.

Soils. High mountain soils are important in determining the range of species that may grow at any site, and consequently the plant communities that develop. Shallow soils tend to support only shrub-dominated communities. The deeper, better-developed soils are often grass-dominated. The prevention of erosion in high mountain areas is therefore of great importance for the protection of many herb-dominated communities. Significant soil loss may lead to changes from grassland to heathland. The exposure of soil will facilitate this process because shrubs are much more likely to establish on bare patches than herbs (Williams 1992). Peat soils typically support hydrophilic communities dominated by mosses but they do not preclude the growth of species found in the humic soil types. There are many examples of grassland and heathland on humified peat, which has presumably become too dry to support bog communities. Kirkpatrick & Bridle (1999) found that soil nutrients (pH, extractable P, Zn and Mg) were important environmental determinants of broad alpine vegetation formations in Australia (including Tasmania), extractable P being the most significant property of the many variables (including non-edaphic) tested.

Wildfire. Based on growth ring data of Snow Gum in various parts of the NSW and ACT high country (Banks 1986) and of *Podocarpus lawreucei* at Blue Cow (McDougall unpublished data), broadscale fires have oeeurred in the high subalpine zone on average 2–3 times per century for the past 300 years. The major fires of January 2003 were consistent with that frequency, being the first through most of the study area since 1939. Despite its intensity, the 2003 fire was locally patehy, missing small areas within scorched landscapes and failing to burn the majority of the alpine zone in Kosciuszko National Park. The frequency of wildfire above the treeline is probably less frequent, perhaps once per century. Regeneration in treeless communities following the 2003 fire was rapid and plants of most species had re-appeared by the following

summer. Only the wet communities (especially those dominated by *Sphagnum cristatum*), herbfields dominated by *Celmisia costiniana* and *Podocarpus*-dominated heathland appear to be slow to recover (Walsh & McDougall 2005).

Biotic determinants

Deaths of individuals or patches of plants are common in the treeless plains of the Australian Alps but rarely extensive. So little is known about the pathogens, parasites and herbivores of this area that the occasional death of a plant is ignored. Extensive patch death of *Poa* species in tussock grasslands is sometimes evident, however, and the cause is known and attributable to the larvae of one of two species of native moth (Alpine Case Moth *Lomera caespitosae*, Alpine Grass Grub *Oncopera alpina*) (Fig. 3) (Carr & Turner 1959a). Infestations appear to be sporadic – common and widespread in some years and then extremely rare for many years. Within dead patches, grass tillers are killed but forbs appear to be



Fig. 2. Needle ice develops in moist, bare soils when the soil surface temperature falls below freezing point. Soil particles are lifted above the needles and are susceptible to erosion once the ice melts. In the example shown, the needles have not melted during the day and have been lifted further by the development of needles beneath.



Fig. 3. Native moths are capable of killing large areas of *Poa* species. The example shown on Mt Twynam (of *Poa fawcettiae*) measured about 1 ha. Forbs seem to be unaffected. The dead mat of grass is stable and will provide protection for the establishment of seedlings, including new *Poa* plants.

unaffected. Minor resprouting of grasses has been observed but the disturbance will usually lead to local changes in plant abundance – the recruitment of grasses and other herbs where a protective cover of dead grass litter persists and the recruitment of shrubs where litter is lost to expose bare ground (Williams 1992).

Macropods are only present in the subalpine part of the study area and even there appear to be uncommon in treeless areas. Wombats are also found in subalpine plains and cause substantial disturbance to plants and soil in the vicinity of their burrows. The effect of native herbivores on the plants and vegetation of treeless vegetation in the Australian Alps is unknown but worthy of investigation. Increases in native herbivore population size, for instance as a result of higher temperatures from global warming, could have a detrimental impact on treeless vegetation, especially where there are also populations of introduced herbivores.

Introduced herbivores undoubtedly have an impact on the flora and vegetation of the treeless plains but the magnitude and consequence of the impact is, in most cases, unknown. The best documented impact of an introduced herbivore comes from long-term monitoring studies of cattle grazing on the Bogong High Plains and Kosciuszko areas (Carr & Turner 1959b, Wimbush & Costin 1979, van Rees 1984, Williams & Ashton 1987, Wahren et al. 1994). Cattle are selective grazers. They prefer inter-tussock herbs (such as *Craspedia* spp., *Celmisia* spp. and *Leptorhynchos squamatus* subsp. *alpinus*) but make up bulk in their diet with tussock grasses (*Poa* spp.). Very little of their diet comprises shrubs and few shrub species (e.g. *Asterolasia trymalioides* and *Grevillea australis*) are apparently palatable. For this reason, cattle spend most of their time in grasslands (including snowpatch communities) (van Rees 1984). Much of their impact in damp areas (such as wetlands and snowpatches) occurs through trampling. Rabbits are rare at the highest altitudes but are apparently slowly moving to higher elevations. They have colonised the Blue Cow ski area (1800 m a.s.l.) in the past decade. Rabbits are known to eat many species and have been found to greatly reduce vegetative cover after fire (Leigh et al. 1987). Hares are a less obvious herbivore – they don't dig burrows and are largely nocturnal – but are surprisingly abundant. Their impact on flora and vegetation has not received the attention it deserves. Pigs, although also rarely seen, leave obvious signs of damage. They dig to detect roots and tubers, and in the process create patches of bare soil – patches of up to 100 m^2 have been observed in Kosciuszko National Park (McDougall & Walsh 2002). Pigs are only present in some subalpine areas of Kosciuszko National Park, the Cobberas and the ACT portions of the study area but could presumably extend their range in the future. They are a significant threat to many plant species and communities. Feral horses are present throughout the study area in variable density. In places where they are common (e.g. the Tantangara area of Kosciuszko National Park and Mt Cobberas area in Victoria), localised trampling damage is easy to find near watering points. Horses are presumably selective grazers. The long-term impact of their grazing in the Australian Alps is undocumented.

Land use and disturbance

For such a small area, the treeless portions of the Australian Alps have been intensively used by people, and the pressures on the plants and vegetation from this use are often obvious.

The degree of use by native peoples prior to European inhabitation is uncertain. The Bogong Moth, which aestivates in the high country, was apparently an important food resource during summer (Flood 1980). The abundant water and numerous plants with tubers and fleshy fruits might have made the area an attractive place for short periods.

Cattle, sheep and horses were brought to the Australian Alps in the mid 19th Century soon after the mountains were first explored by Europeans. Thereafter, the mountains commonly provided feed for stock in times of drought. In the drought of 1902/03 there are thought to have been 100,000 sheep in the Victorian high country alone (Carr & Turner 1959a). Grazing in the high mountains was regulated in the early 20th Century through the allocation of grazing leases. By the mid-20th Century, it was clear that stock were causing considerable damage to plant communities and, more importantly, erosion of soils, which could affect the capacity of the areas to support the dams required for the production of hydro-electricity. Stock grazing was gradually phased out in many parts of the Australian Alps between 1950 and 1970. Small areas of privately-owned treeless country in NSW are still grazed but stock grazing is no longer permitted in Kosciuszko National Park and has not been a feature of the ACT high country. Cattle grazing has recently (mid-2005) been legislated to cease in the Alpine National Park in Victoria, but grazing is still permitted in adjacent areas of State Forest, some of which include treeless subalpine vegetation (e.g the Nunniong Plateau).

Graziers are known to have lit fires in treeless country in late autumn to improve the pick for stock in the following snow-free season (Downes 1961). The frequency and severity of these fires was not documented. Given that conditions at that time of the year would rarely be favourable to the spread of fire it is likely that any fires lit by graziers would have been very localised and cool. If they had been frequent and widespread, obligate seeders such as *Grevillea australis*, *Epacris gunnii* and *Asterolasia trymaliodes* could not have survived to be as abundant and widespread as they are now. In addition, frequent fires do not show up in the growth ring data of high subalpine Snow Gum (Banks 1986). There is no evidence that aborigines burnt the high country and if macropods were as scarce then as they are now in the higher parts, it is hard to see why they would have used broadscale fire to improve hunting conditions by promoting green pick. It is plausible, however, that some of the fires lit in lower country may have occasionally burnt into alpine areas.

Prospecting for gold at Kiandra (in Kosciuszko National Park) in the 19th Century must have caused great damage to vegetation and soils because large, unvegetated scars from erosion and soil removal are still visible. Gold was discovered there in late 1859 and by February the next year there were 1500 miners living in the treeless Kiandra plains area (Mitchell 1985).

The production of hydro-electricity in the Kosciuszko area and Bogong High Plains in the 1950s required the construction of dams, aqueducts, powerlines and a network of service roads, and caused the destruction or disturbance of thousands of hectares of treeless vegetation. Changes to wetland vegetation may also have occurred through the diversion of water. Many weeds were probably introduced at this time both inadvertently and through the use of exotic species for soil stabilisation. A seed mix of exotic species containing cultivars of *Agrostis capillaris, Avena sativa, Dactylis glomerata, Festuca rubra, Lolium perenne, Poa pratensis, Secale cereale* and *Trifolium repens* was developed specifically to treat disturbed areas (Clothier & Condon 1968).

The high country environment now attracts many visitors both in summer, for the scenery, and in winter, for snow sports. About 100,000 people visit the alpine area of Kosciuszko National Park during the snow-free season (Johnston & Growcock 2005) – many of these walk to Mt Kosciuszko, the highest point in Australia. Most forms of tourism have required the construction of infrastructure, such as walking tracks, accommodation and ski runs. The damage to vegetation and soils on the track from the top of the Thredbo chairlift to Mt Kosciuszko necessitated the construction of a raised metal walkway.

A consequence of a long and varied use of treeless high mountain country by people is the presence of many feral animals (see above) and weeds. The highest parts of the Australian Alps contain relatively few weeds (compared with many plant communities at lower elevations) (Mallen 1986). The high mountain climate is not a barrier to weeds, however. Extremely invasive plants such as *Hieracium* spp. have been discovered at the treeline in Victoria and New South Wales only in the last decade (Morgan 2000), mostly in or near ski villages. Treeless vegetation is likely to face increasing pressure from plant invasions because of global warming and the continued use of non-native plants in some ski resort gardens and in revegetation (McDougall et al. 2005).

Methods

Data collection

Floristic data were obtained from previous surveys of treeless vegetation. Additional quadrats were sampled by us to fill in the spatial gap in data in Kosciuszko National Park and nearby areas. Quadrats containing isolated trees, tree patches (e.g. *Eucalyptus lacrimans*) or mallee eucalypts (e.g. *E. debeuzevillei*) within a treeless landscape were included. The data were collected randomly using a range of quadrat sizes (Table 1). Using a nested quadrat technique McDougall (1978) found that a quadrat size of 8 m^2 was sufficient to capture 95% of species in a diverse open heathland on the Bogong High Plains in the Victorian high country. In all of the surveys, quadrats were placed in what was perceived to be homogeneous vegetation. Any differences in quadrat size should therefore not greatly affect the composition of the resulting quadrats. The Braun-Blanquet cover – abundance scale or slightly modified versions were used in each of the surveys.

Data analysis

Because of taxonomic changes since the surveys of the 1980s, it was necessary to aggregate some taxa prior to analysis: *Agrostis hiemalis* sp. agg. (includes *A. bettyae, A. joyceae, A. propinqua, A. thompsoniae*), *Gentianella*

Table 1. Floristic data used in the classification

Survey	Location	Quadrat dimensions (m)	No. quadrats available	No. quadrats used
Ecology Australia (2003)	NSW ski resorts	5 x 5, 10 x 10[a]	176	102
Gilmour et al. (1987), Helman et al. (1988)[b]	A.C.T.	25 x 20	28	26
McDougall (1982)	Bogong High Plains, Victoria	4 x 5	363	343
This paper	Other areas, NSW	5 x 5	361	329
Walsh et al. (1984)	Other areas, Victoria	4 x 5	464	422
TOTAL			**1392**	**1222**

[a] the larger quadrat size was used in heathy vegetation
[b] full quadrat data from Helman & Gilmour (1985) could not be located and were therefore not used

spp. (except for *G. muelleriana* subsp. *alpestris* and subsp. *willisiana*), *Craspedia* spp. (except those endemic to Kosciuszko National Park and *Craspedia alba*, which was not recorded in quadrats by McDougall (1982)), *Celmisia* spp. (except *C. sericophylla*), *Geranium potentilloides* sens. lat., *Leucopogon* spp. (including only *L. hookeri* and *L. montanus*, which were aggregated by McDougall (1982) because of difficulties with identification when not in flower), *Prasophyllum* spp., *Solenogyne* spp. (includes *S. dominii* and *S. gunnii*), *Stylidium* spp. (includes *S. armeria* and *S. montanum*). Introduced taxa were not used in the classification. Species nomenclature follows Ross & Walsh (2003) and Harden (1991–1995) except where recent taxonomic changes have been published.

A total of 1392 quadrats was analysed using the software package Primer v5. Cover scale values were square-root transformed prior to the calculation of similarities using a Bray Curtis coefficient. The cover values of R, + and 1, each indicating cover values of less than 5% , were amalgamated and assigned a value of 1. The routine CLUSTER was used with the similarity matrix to create a classification of quadrats using the group average cluster mode. Because of the large size of the data set, it was not possible to generate a dendrogram of quadrats. Quadrat clusters were instead sorted by hand using the output of the CLUSTER analysis.

Diagnostic taxa for each community were determined using a G-test of independence, comparing the frequency of a species within a community with its frequency in all quadrats (Sokal & Rohlf 1981). Taxa were listed as diagnostic for significant differences in frequency with $P < 0.01$. Taxa with a frequency of greater than 40% that were not significantly different from their expected frequency are listed in the descriptions below as Other Common Taxa.

Inter-relationships between the identified communities were assessed by running CLUSTER on frequency data for diagnostic species in each community without transformation.

Results

Floristic composition

Based on the quadrat data presented in this paper, previously published lists (Thompson & Gray 1981, Helman & Gilmour 1985, Helman et al. 1988) and our personal observations, 710 native taxa from 82 families have been recorded in the treeless high mountain plains and peaks of the Australian Alps (Appendix 1). The best represented families are Asteraceae (16.3% of the flora), Poaceae (10.6%), Cyperaceae (7.0%), Orchidaceae (4.4%), Fabaceae (4.1%), Apiaceae (3.7%), Ericaceae (3.7%), Scrophulariaceae (3.7%), Myrtaceae (3.4%), Juncaceae (3.0%), Ranunculaceae (3.0%), Rubiaceae (2.5%), and Caryophyllaceae (2.0%).

Of the 710 native taxa recorded, 217 (30.6%) are largely restricted to the treeless vegetation of the Australian Alps (although some extend for a short distance into the surrounding woodland vegetation). A further 101 taxa (14.2%) are restricted to treeless vegetation in the Australian Alps but also occur beyond the Australian mainland – 91 taxa are also found in the Tasmanian high country (Kirkpatrick 1997) and 26 are part of the New Zealand mountain flora (Mark & Adams 1995).

The flora has strong affinities with the high mountain floras of Tasmania, New Zealand and South America. Several of the genera that are common to these floras are more or less restricted to alpine and subalpine environments (e.g. *Aciphylla, Argyrotegium, Celmisia, Chionohebe, Colobanthus, Gentianella, Kelleria, Uncinia*).

One hundred and thirty-one non-native taxa have been recorded in natural vegetation in the study area (Appendix 1). Most of these were recorded rarely or not at all in the quadrat surveys. Only sixteen taxa were recorded in more than 1% of quadrats (*Acetosella vulgaris* 42.9%, *Hypochaeris radicata* 26.5%, *Trifolium repens* 14.9%, *Taraxacum officinale* 8.7%, *Cerastium glomeratum* 7.8%, *Cerastium vulgare* 7.4%, *Poa pratensis* 2.5%, *Aphanes arvensis* 2.4%, *Holcus lanatus* 1.8%, *Anthoxanthum odoratum* 1.4%, *Trifolium dubium* 1.4%, *Vulpia bromoides* 1.3%, *Aira caryophyllea* 1.1%, *Agrostis capillaris* 1.0%, *Myosotis caespitosa* 1.0%).

Significant plant taxa

Thirteen taxa occurring in treeless vegetation are listed in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as threatened. Fourteen taxa are listed as threatened under State legislation but not in the EPBC Act: *Carex archeri, C. raleighii, Euphrasia scabra, Prasophyllum bagoensis, P. retroflexum* (*Threatened Species Conservation Act 1995*), *Brachyscome* sp. 3, *Carex cephalotes, Celmisia sericophylla, Deyeuxia affinis, Epilobium willisii, Euphrasia scabra, Juncus antarcticus, Poa saxicola, Utricularia monanthos, Wahlenbergia densifolia* (*Flora and Fauna Guarantee Act 1988*). Under IUCN criteria for the evaluation of threatened status (IUCN 2001), a further 17 taxa may be eligible for listing as threatened nationally. These and listed taxa are described below. The status under the EPBC Act is shown after the Family name; the IUCN status for species that may be eligible is underlined (E = endangered; V = vulnerable).

Argyrotegium nitidulum (Asteraceae; V), like many other alpine species, is rare throughout its range but is not uncommon where it is found. Apart from occasional damage to leaves by an unknown moth (NSW National Parks and Wildlife Service 2000), there appears to be little immediate threat to this species. It has been recorded close to one ski resort but is not currently threatened by development there. Its conservation status possibly should be reviewed.

Bossiaea riparia (Gulf Plain) (Fabaceae; V). The greyish, prostrate, fine-branched form of treeless vegetation appears quite distinct from the taller riparian form found at lower altitudes, and warrants recognition at species level (Jim Ross, National Herbarium of Victoria, pers. comm.). It is largely restricted to the Murrumbidgee River valley between the ACT and Kosciuszko National Park. Although it is locally abundant, most populations are small and on private land. There are a few pre-1900 records of this species for Victoria but it appears now to be extinct in that State.

Bulbine aff. *glauca* (Nungar Plain) (Asphodelaceae; E) has only been recorded at two sites (Nungar Plain and Snowy Plain) and is threatened at both by pig rooting and at one by cattle grazing.

Calotis glandulosa (Asteraceae; V) occurs in Kosciuszko National Park and the Monaro Plains near Cooma. In Kosciuszko National Park it is locally abundant in the Tantangara area and seems to favour disturbed sites.

Calotis pubescens (Asteraceae; E) is only known to occur at Nungar Plain in Kosciuszko National Park (apparently only in Community 31, described below), although there are two old records from other sites, which have not been relocated during recent searches. The extant population is threatened by pig rooting.

Carex paupera (Cyperaceae; V) is endemic in Victoria and known from a few populations on the Dargo High Plains, Bogong High Plains near Mt Jim, and plains near Mt Hotham. Some populations are reasonably extensive, but they occur in areas prone to disturbance. There is some evidence that the species is actually a coloniser of disturbed ground and may be at least partly disturbance-dependent. There is uncertainty about the distinctness of this species from the widespread, variable *C. inversa*.

Deyeuxia affinis (Poaceae; V) is known from only two sites on the Bogong High Plains but is commoner on the Main Range of Kosciuszko National Park. It is no longer subjected to cattle grazing pressures but the small population size would justify its threatened status.

Deyeuxia talariata (Poaceae; V) is largely confined to the Cobberas Mountains and the Nunniong Plateau where known from only 4 populations. It is threatened by disturbance of bogs through the activities of feral horses. Two of the known sites were burnt in the 2003 bushfires.

Dillwynia palustris (Fabaceae; E) is a prostrate pea known from five sites (two in Kosciuszko National Park, two on non-reserve tenures nearby and one in State Forest). The populations in Kosciuszko National Park seem to be small and are threatened by grazing and trampling by pigs and feral horses. Both Kosciuszko National Park populations were burnt in 2003; one had regenerated 12 months later (Walsh & McDougall 2005).

Discaria nitida (Rhamnaceae; V) occurs in about 20 populations, mostly in Kosciuszko National Park. Most populations are at or below the lower treeline. Some Kosciuszko National Park populations are threatened by weeds.

Diuris pedunculata (Orchidaceae; E) has a large range in NSW. It was found recently at Snowy Plain, freehold land on the eastern side of Kosciuszko National Park, and may also have been recorded from the Kiandra area. It may have been overlooked elsewhere in the study area because of its superficial similarity to the more common *D. monticola*.

Eucalyptus lacrimans (Myrtaceae; V) is locally dominant in the Kiandra – Tantangara – Long Plain area and to the east of Adaminaby (and is the dominant of Community 34, described below). The species would probably meet the criteria for listing as Vulnerable as most stands near Adaminaby are on private, grazing land where there is little or no recruitment evident and much death of isolated trees in paddocks. Many stands in Kosciuszko National Park appear to be in poor health and most contain a mix of live and dead trunks with little recruitment. The reasons for the deaths and poor recruitment are worthy of investigation. Some examples were burnt in the 2003 fires.

Euphrasia crassiuscula subsp. *glandulifera* (Orophulariaceae; V) is confined to a few known populations on the higher parts of the Victorian Alpine National Park (Mt Bogong and Bogong High Plains). All populations are now protected from cattle grazing. Some were extensively burnt in the 2003 fires but recruitment from seed has been recorded since.

Euphrasia eichleri (Orophulariaceae; V) is confined to a few known populations on the higher parts of the Victorian Alpine National Park (Mt Bogong and Bogong High Plains). All populations are now protected from cattle grazing. It is closely related to *E. alsa*, similarly a localised endemic on the Kosciuszko Main Range. Several populations were burnt in the 2003 fires but new plants have been recorded since.

Euphrasia sp. 3 (Ramshead Range) (Orophulariaceae; E) is a tiny annual, which appears to be restricted to the Ramshead Range between Charlottes Pass and South Ramshead in Kosciuszko National Park, where it is extremely rare. Whilst there are few apparent threats (feral horse grazing and trampling by horses and tourists), its small population size may make it especially vulnerable to impacts from global warming.

Galium roddii (Rubiaceae; E) is relatively common on the slopes of Cave Creek in Kosciuszko National Park and occurs in smaller populations elsewhere, at Currango and Long Plains. The main population however is threatened by weed competition, especially *Sedum acre*.

Genoplesium turfosum (Orchidaceae; E) is only known from two sites (in northern Kosciuszko NP and in Namadgi National Park). Despite our recent surveys, new populations were not located, although the species is somewhat cryptic.

Kelleria laxa (Thymelaeaceae; V) occurs only in the vicinity of Mt Jim on the Bogong High Plains (Victorian Alpine National Park). About 20 small populations are known in an area of about 2 km^2, varying from a few cm^2 to a few m^2. All populations were subject to summer grazing prior to 2005. The species is also known from New Zealand, but morphological and DNA evidence suggests the Australian plants may constitute a distinct taxon.

Lobelia gelida (syn. *Pratia gelida*; Campanulaceae; V) is confined to a few small populations in Victoria, on Mt Buffalo and near Mt Howitt. At these sites it may be locally abundant in shallow seasonal pools. All populations are now protected from cattle grazing and most are in areas unlikely to be otherwise damaged.

Prasophyllum bagoensis (Orchidaceae; E) This orchid is only known from McPhersons Plain (on freehold land and NSW State Forest lease), where it is threatened by pigs and feral horses.

Prasophyllum nigropedium (Orchidaceae; E) is confined to a few small populations near the Cobberas Mountains in the Alpine National Park and on the nearby Nunniong Plateau. It is subject to grazing and damage by feral horses which are abundant in these areas. *Prasophyllum nigropedium* has been recently segregated from *P. morganii*. The latter species (listed as Vulnerable under the EPBC Act) is now regarded as extinct, being known from subalpine vegetation at Cobungra, Victoria, and last collected in 1933.

Prasophyllum retroflexum (Orchidaceae; V) is rare and restricted to the plains in and around Kiandra but has probably been overlooked because of its similarity to the more common species there (e.g. *P. sphacelatum*), and its short flowering period.

Prasophyllum sp. aff. *canaliculatum* (Orchidaceae; E), is an undescribed orchid that is only known from McPhersons Plain (on freehold land and NSW State Forest lease) (David Jones, CSIRO, pers. comm.) where it is threatened by pigs and feral horses.

Ranunculus anemoneus (Ranunculaceae; V) was apparently close to extinction when the Kosciuszko area was grazed by domestic stock. It is now locally common in a range of communities on the Main Range between Mt Kosciuszko and Mt Jagungal.

Rutidosis leiolepis (Asteraceae; V) is known from only a few sites in the Monaro Plains area south of Canberra and was recorded during the current survey from several grassland/ open heath sites near Kiandra (e.g. Long Plain and Happy Jacks Plain). Feral horses and pigs are abundant in these areas and cause significant local damage to the vegetation containing this daisy.

Rytidosperma pumilum (Poaceae; V), whilst occurring in alpine areas of New Zealand, is known from a single population in Australia, on the Kosciuszko Main Range. The Australian population numbers thousands of plants in an area of only a few ha. In the long term it is indirectly threatened by trampling by bushwalkers (McDougall & Wright 2004) and by loss of habitat through climate change.

Rytidosperma vickeryae (Poaceae; E) occurs in *Sphagnum*-dominated communities of a few subalpine tributaries of the upper Snowy River (e.g. Betts Creek, Perisher Creek) but has been recorded only once beyond that area (Happy Jacks Plain). Some populations may be threatened by future ski development.

Thesium australe (Santalaceae; V) has been recorded from limestone-derived soils near Cave Creek (Kosciuszko National Park) and soils of volcanic origin near the Cobberas mountains in Victoria. Population numbers appear to fluctuate widely from year to year. This species was once a widespread component of grasslands in Queensland, New South Wales, Victoria and Tasmania but is now largely confined to a few highland sites and coastal headlands on the mainland.

Viola improcera (Violaceae; V) has been recorded in the ACT (in the Mt Scabby / Mt Kelly area) and in Victoria on the Nunniong Plateau and Mt Useful. Although not yet recorded in NSW, it probably occurs there, the ACT records being close to the border. In the ACT, this small stoloniferous herb grows in heathland (Helman et al. 1988) and mallee shrubland.

Wahlenbergia densifolia (Campanulaceae; V), in Victoria, is only known from a few subalpine sites (e.g. Cobberas, Nunniong Plateau). Although more widespread in NSW it may be eligible for listing. Three populations were found in the current study in Kosciuszko National Park. Two of these sites (Happy Jacks Plain and Nungar Plain) are frequently damaged by pigs, which preferentially dig in the community containing this species (Community 31, described below). In NSW, this species has also been recorded at Mt Gingera, the Guthega area and the Tinderry Range.

Xerochrysum palustre (Asteraceae; V) is mostly found in lowland and mid-elevation wetlands in Tasmania, Victoria and New South Wales but was recorded during the current study at several sites in the Tantangara – Kiandra area of Kosciuszko National Park.

Two taxa of treeless vegetation (*Actinotus moorei* and *Epilobium willisii*) are now extinct on the mainland but persist in alpine vegetation in Tasmania.

Table 2. Summary of Communities. Distribution: ACT = Australian Capital Territory (and adjacent parts of Kosciuszko NP); BB = Baw Baw – Lake Montain area; BHP = Bogong High Plains; KMR = Kosciuszko Main Range and adjoining subalpine plains; KSUB = other subalpine plains of Kosciuszko National Park and surrounds; VICO = Victorian sites other than BHP and BB (e.g. Mt Buller, Mt Buffalo, Cobberas, Wellington Plains); W = widespread (i.e. throughout most of study area)

Group	Community	Distribution (lineal extent (km))	Habitat	Native taxa/ quadrat	Weeds / quadrat	Altitude (m)	Usual dominants of upper stratum
I – wet heathlands (bogs), wetland margins & valley grassland	1: Baw Baw – Lake Mountain wet heathland	BB (65)	Valley - wet	22.8	0.1	1270 – 1570	*Epacris paludosa*, *Richea continentis*
	2: *Richea continentis – Carpha nivicola – Sphagnum cristatum* wet heathland	W (230)	Valley - wet	17.4	0.1	1320 – 2100	*Baeckea gunniana*, *Richea continentis*
	3: *Baeckea gunniana – Callistemon pityoides - Sphagnum cristatum* wet heathland	W (280)	Valley - wet	25.0	1.3	1160 – 1840	*Baeckea gunniana*, *Epacris paludosa*
	4: *Epacris* moist heathland	BHP, KMR (125)	Valley - moist	19.2	0.3	1650 – 2150	*Epacris glacialis*, *E. gunnii*, *E. petrophila*
	5: Alpine valley grassland	ACT, KSUB (25)	Valley - moist	16.8	0.6	1740 – 2010	*Poa costiniana*
II – damp herbfields, fens & waterways	6: *Lobelia surrepens – Ranunculus millanii* herbfield	W (275)	Valley – wet & dry	12.9	0.6	1090 – 1770	*Lobelia surrepens*, *Ranunculus millanii*
	7: *Hypericum japonicum – Ranunculus pimpinellifolius* herbfield	W (200)	Valley - wet	21.8	4.6	1180 – 1740	*Hypericum japonicum*, *Ranunculus pimpinellifolius*
	8: Fen	W (210)	Valley - wet	13.6	0	1300 – 1920	*Carex gaudichaudiana*
	9: Aquatic	W (270)	Valley - wet			1000 – 1600	Nil
III – gravelly pavement herbfields	10: Short alpine herbfield	BHP, KMR (120)	Valley - wet	17.0	0.0	1600 – 2200	*Caltha introloba*, *Oreobolus pumilio*
	11: *Celmisia sericophylla* herbfield	BHP (25)	Snowpatch - wet	13.0	0.6	1560 – 1820	*Celmisia sericophylla*
IV – snowpatch herbfields	12: *Coprosma niphophila – Colobanthus nivicola* snowpatch feldmark	KMR (7)	Snowpatch - dry	15.0	0.5	2050 – 2200	*Colobanthus nivicola*, *Coprosma niphophila*
	13: *Neopaxia australasica – Ranunculus niphophilus* snowpatch herbfield	KMR (35)	Snowpatch - wet	14.0	0.4	1920 – 2170	*Neopaxia australasica*, *Plantago muelleri*

Group	Community	Distribution (lineal extent (km))	Habitat	Native taxa/ quadrat	Weeds / quadrat	Altitude (m)	Usual dominants of upper stratum
V – subalpine valley & fertile grasslands	14: Subalpine valley grassland	W (220)	Valley - moist	25.9	2.1	1020 – 1680	*Poa costiniana*
	15: Snowy Range Grassland	VICO (90)	Plains	27.7	2.1	1260 – 1760	*Poa costiniana*
	16: Victorian subalpine basalt grassland	VICO (145)	Plains	25.3	4.9	1200 – 1620	*Poa hiemata*
VI – closed alpine grasslands	17: *Poa fawcettiae* – *Celmisia costiniana* snowpatch grassland	BHP, KMR (115)	Snowpatch	11.4	0.8	1710 – 2160	*Celmisia costiniana*, *Poa fawcettiae*
	18: *Poa fawcettiae* - *Uncinia sulcata* grassland	KMR (35)	High slopes	11.3	0.1	1970 – 2200	*Poa fawcettiae*, *Uncinia sulcata*
	19: *Chionochloa frigida* grassland	KMR (25)	Sheltered slopes	16.8	0.6	1780 – 2110	*Chionochloa frigida*, *Poa fawcettiae*
VII – high altitude grasslands & open heathlands	20: Short turf snowpatch grassland	BHP (25)	Snowpatch	17.4	2.1	1670 – 1850	*Carex hebes*, *Rytidosperma nudiflorum*
	21: Bogong High Plains *Hovea montana* heathland	BHP (25)	Sheltered slopes	21.4	1.8	1680 – 1840	*Hovea montana*
	22: *Poa fawcettiae* – *Euphrasia collina* grassland	KMR (40)	Valleys & saddles	20.1	0.9	1740 – 2190	*Poa fawcettiae*
	23: *Grevillea australis* – *Nematolepis ovatifolia* open heathland	KMR (45)	Slopes	22.8	0.8	1600 – 2030	*Grevillea australis*, *Nematolepis ovatifolia*
	24: Bogong High Plains *Poa costiniana* grassland	BHP (15)	Plains	21.2	2.7	1570 – 1840	*Poa costiniana*
	25: Bogong High Plains *Poa hiemata* grassland	BHP (30)	Plains	20.7	1.6	1380 – 1930	*Poa hiemata*
	26: Bogong High Plains *Grevillea australis* – *Phebalium squamulosum* open heathland	BHP (35)	Slopes	23.4	1.5	1560 – 1960	*Grevillea australis*
	27: Bogong High Plains *Kunzea muelleri* open heathland	BHP (35)	Slopes	19.9	0.6	1630 – 1900	*Kunzea muelleri*
	28: Snowy Range open heathland	VICO (100)	Plains	23.4	2.2	1340 – 1680	*Hovea montana*
	29: Victorian shale *Hovea montana* heathland	VICO (55)	Slopes	20.2	1.3	1460 – 1740	*Hovea montana*

VIII – subalpine heathland	30: *Poa hiemata – Poa clivicola* grassland	ACT, KSUB (120)	Plains	29.9	2.1	1250 – 1810	*Poa hiemata, Poa clivicola*
	31: *Poa hookeri* grassland	KSUB (75)	Plains	27.4	2.4	1200 – 1420	*Poa hookeri*
	32: *Hovea montana - Poa phillipsiana* open heathland	VICO (125)	Plains	21.0	1.2	1160 – 1700	*Poa phillipsiana*
	33: Northern Alps *Hovea montana* open heathland	ACT, KSUB (80)	Slopes	24.0	1.3	1330 – 1800	*Hovea montana*
	34: *Eucalyptus lacrimans* low open woodland	KSUB (35)	Slopes	26.2	2.2	1270 – 1470	*Eucalyptus lacrimans*
	35: *Bossiaea foliosa – Epacris petrophila* heathland	KSUB (10)	Plains	17.8	1.5	1320 – 1360	*Bossiaea foliosa, Epacris petrophila*
	36: Broadway *Bossiaea foliosa* closed heathland	KSUB (10)	Slopes	36.6	1.8	1250 – 1350	*Bossiaea foliosa*
	37: Northern Alps Epacris - *Kunzea* open heathland	KSUB (90)	Slopes	25.9	0.7	1250 – 1620	*Epacris gunnii, E. petrophila, Kunzea muelleri*
IX – limestone grassland	38: *Themeda triandra – Leucochrysum albicans* grassland	KSUB (1)	Slopes	16.2	6.2	1200 – 1220	*Themeda triandra, Leucocrysum albicans*
X – short alpine heathlands	39: Kosciuszko alpine *Epacris - Kunzea* open heathland	KMR (40)	Slopes	15.2	0.4	1860 – 2220	*Epacris gunnii, Kunzea muelleri*
	40: *Epacris gunnii – Chionohebe pulvinatus* feldmark	KMR (8)	High ridges	14.8	0.5	2010 – 2150	*Epacris gunnii*
	41: Bogong High Plains *Epacris - Kunzea* open heathland	BHP (20)	High ridges	14.3	0.1	1630 – 1880	*Epacris gunnii*
XI – western subalpine open heathland	42: *Epacris celata – Poa clivicola* open heathland	KSUB (1)	Plains	26.0	2.0	1100	*Epacris celata, Epacris gunnii*
XII – upper Murrumbidgee dwarf heathland	43: *Bossiaea riparia* dwarf heathland	KSUB (15)	Slopes	24.3	3.5	1220 – 1280	*Bossiaea riparia*
XIII – Baw Baw open heathlands	44: *Pultenaea muelleri* open heathland	BB (15)	Rocky slopes	21.6	2.6	1320 – 1540	*Pultenaea muelleri*
	45: *Epacris petrophila* open heathland	BB (5)	Slopes	21.5	0.3	1310 – 1480	*Epacris petrophila*

Group	Community	Distribution (lineal extent (km))	Habitat	Native taxa/ quadrat	Weeds / quadrat	Altitude (m)	Usual dominants of upper stratum
XIV – high altitude closed heathlands	46: *Nematolepis ovatifolia – Prostanthera cuneata* closed heathland	KMR (75)	Slopes	18.0	0.8	1420 – 2040	*Nematolepis ovatifolia, Prostanthera cuneata*
	47: Bogong High Plains *Phebalium squamulosum – Bossiaea foliosa* closed heathland	BHP (25)	Slopes	16.5	0.9	1610 – 1830	*Bossiaea foliosa, Prostanthera cuneata*
XV – central Victorian Alps rocky open heathlands	48: *Podolobium alpestre - Euryomyrtus ramosissima* open heathland	VICO (30)	Rocky peaks and cliffs	14.6	0.7	1380 – 1800	*Euryomyrtus ramosissima, Podolobium alpestre*
	49: Snowy Range – Mt Buffalo *Kunzea muelleri* heathland	VICO (90)	Rocky slopes	17.4	0.6	1380 – 1740	*Kunzea muelleri*
	50: *Olearia phlogopappa – Podolobium alpestre* closed heathland	VICO (160)	Rocky outcrops	18.5	1.3	1660 – 1760	*Podolobium alpestre, Olearia phlogopappa*
XVI – rocky outcrop open heathland	51: *Austrodanthonia alpicola – Grevillea australis* open heathland	BHP, KMR (190)	Rocky outcrops – dry	21.2	1.5	1420 – 2180	*Austrodanthonia alpicola, Brachyscome rigidula*
XVII – ACT rocky outcrop mallee shrubland	52: *Eucalyptus debeuzevillei* mallee shrubland	ACT (6)	Rocky slopes	19.8	1.0	1720 – 1810	*Eucalyptus debeuzevillei*
XVIII – boulder heathlands	53: *Podocarpus lawrencei – Epacris paludosa* closed heathland	W (180)	Valley - moist	22.2	0.8	1280 – 1950	*Epacris paludosa, Podocarpus lawrencei*
	54: *Podocarpus lawrencei* closed heathland	W (200)	Block stream - dry	8.8	0.5	1400 – 2080	*Podocarpus lawrencei*
XIX – boulder herbaceous communities	55: *Carex appressa* sedgeland	BHP (7)	Block stream - moist	12.5	2.6	1710 – 1800	*Carex appressa*
	56: *Poa helmsii* grassland	BHP (7)	Block stream - dry	12.4	2.0	1730 – 1800	*Poa helmsii*

Plant community descriptions

The Cluster analysis identified 56 communities at the 29.3% similarity level (Table 2). Below this level of similarity, some groups regarded as representing communities of well-defined habitat were combined with quadrats of other habitat. Above this level of similarity, there was a greatly increased number of communities that we felt would be difficult to identify in the field. The 170 quadrats that did not fit within groups at this similarity were not used in the classification. Some perhaps represent under-sampled communities. Others may have been inadvertently sampled across community boundaries. When the frequencies of the diagnostic species in the 56 communities were re-analysed using Primer, 19 Vegetation Classes (in the sense of Keith (2004) were identified at the 20% similarity level (Fig. 4). At a lower similarity level, disparate communities were amalgamated, often because of low species richness (e.g. alpine grasslands of Kosciuszko National Park (Communities 17, 18 and 19) with rocky open heathlands of the central Victorian Alps (Communities 48, 49 and 50)).

In the descriptions of the communities below, the community names were developed using a system of priorities. A vernacular name was used if this was unambiguous. The name 'tall alpine herbfield', used by Costin (1954) for herb-rich communities of dry alpine sites in Kosciuszko National Park, was not used by us because it contained several of our identified communities. Where there was no unambiguous vernacular name, a name was constructed using features that were unique to the community (e.g. usual dominants, location, habitat, diagnostic species) and a structural base name (e.g. heathland, grassland).

In the descriptions below, diagnostic taxa are grouped by life form (shrub or herb) and listed in decreasing order of frequency (with % frequency in parentheses). Other common, but not diagnostic taxa are listed where the frequency is greater than 40%. Significant taxa are those listed and described above. All weeds occurring within a community are listed (with % frequency in parentheses).

The altitudinal range of each community is presented as Lowest – Mean – Highest. Management issues are discussed under the assumption that cattle grazing will no longer be permitted in the Alpine National Park.

Group I – wet heathlands (bogs), wetland margins & valley grassland

Community 1: Baw Baw – Lake Mountain wet heathland

Equivalent communities: Wet alpine heathland, sub-communities 9.1, 9.2, 9.3 (Walsh et al. 1984).

Baw Baw – Lake Mountain wet heathland is restricted to the Baw Baw Plateau and Lake Mountain areas, occurring in broad valley floors and lower slopes of relatively low relief. Permanent water is a feature, either as pools or as slow-flowing streams. Topographically lower sites support dense heath to c. 1 m high, composed mainly of *Richea continentis*, *R. victoriana*, *Baeckea gunniana*, *B. utilis*, *Epacris paludosa*, *E. petrophila* in a complex with abundant *Sphagnum cristatum* forming hummocks and hollows associated with a variety of herbs such as *Astelia alpina*, *Blechnum penna-marina*, *Brachyscome obovata*, *Drosera arcturi*, *Nertera granadensis*, *Erigeron paludicola*, *Euphrasia gibbsiae* subsp. *subglabrifolia*, and *Isolepis* spp. This complex is typically surrounded upslope by a drier heath dominated by *Olearia algida*, *Ozothamnus* sp.1, *Tasmannia vickeriana*, *Trochocarpa clarkei*, *Pultenaea muelleri*, *Leionema phylicifolium* (Lake Mountain only). These mountains are disjunct from the Alps of the main Dividing Range and consequently contain a relatively high percentage of locally endemic or restricted taxa. This community is localised but well protected and under minimal threat. Both plateaux contain areas used for nordic skiing on groomed trails, and some cleared and groomed downhill ski slopes exist on Mt Baw Baw. There is a low level of weed intrusion as a consequence of the latter. Both areas are used for bushwalking and there are local effects associated with this around popular campsites (particularly on the Baw Baw plateau). Grazing has not been permitted at either area since 1975 but a few wild cattle persisted at least until recently near Mt Baw Baw.

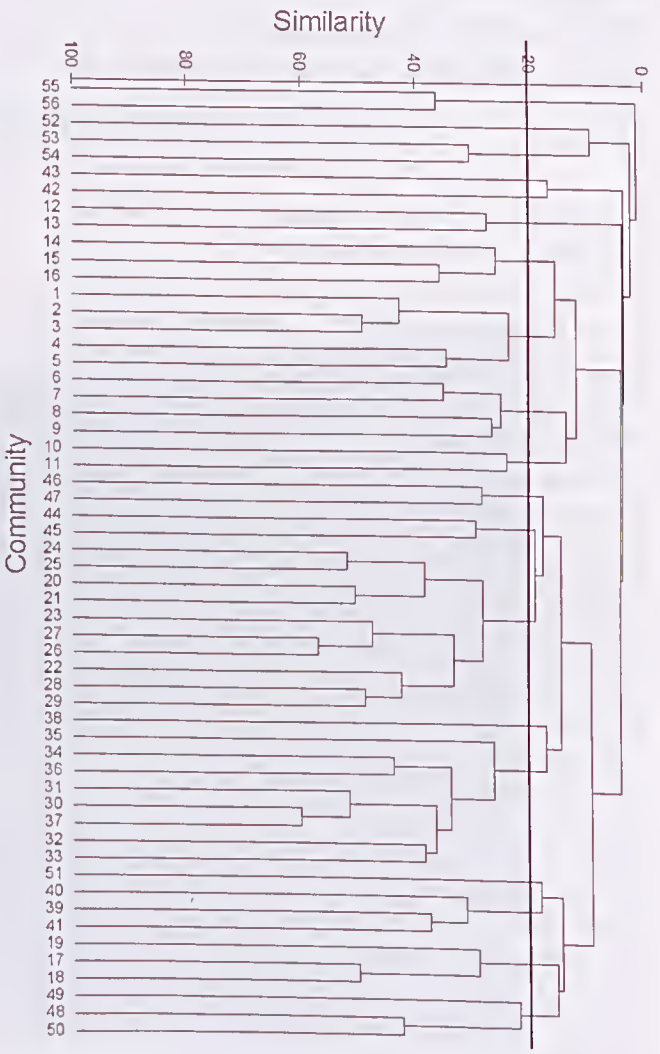


Fig. 4. Dendrogram showing relationships between communities. The 20% line of similarity is shown, at which 20 broad community groups were identified.

No. quadrats 53; Native taxa / quadrat 22.8 ± 0.8; Total native taxa 127; Weeds /quadrat 0.1 ± 0.0; Total weed taxa 3

Altitude: 1270 – 1410 – 1570 m.

Diagnostic Taxa: Shrubs *Epacris paludosa* (84), *Richea continentis* (82), *Olearia algida* (80), *Baeckea gunniana* (49), *Callistemon pityoides* (38), *Baeckea utilis* (29), *Epacris petrophila* (27), *Orites lancifolia* (25), *Wittsteinia vacciniacea* (22), *Ozothamnus* sp. 1 (18), *Pultenaea muelleri* (16), *Tasmannia vickeriana* (16), *Coprosma perpusilla* (13), *Trochocarpa clarkei* (9), *Coprosma nitida* (7), *Leptospermum grandifolium* (7); **Herbs** *Astelia alpina* (89), *Gentianella* spp. (82), *Empodisma minus* (75), *Celmisia* spp. (62), *Sphagnum cristatum* (62), *Thelymitra cyanea* (56), *Nertera granadensis* (53), *Euphrasia gibbsiae* subsp. *subglabrifolia* (49), *Oreobolus distichus* (47), *Carpha nivicola* (45), *Isolepis aucklandica* (44), *Lycopodium fastigiatum* (42), *Plantago alpestris* (36), *Blechnum penna-marina* (33), *Gonocarpus micranthus* (33), *Hydrocotyle algida* (33), *Erigeron paludicola* (31), *Epilobium gunnianum* (29), *Brachyscome obovata* (27), *Herpolirion novae-zelandiae* (27), *Ranunculus collinus* (27), *Carex appressa* (25), *Drosera arcturi* (24), *Caltha introloba* (20), *Ranunculus gunnianus* (20), *Juncus saudwithii* (18), *Schoenus calyptratus* (18), *Euchitan callinus* (16), *Huperzia australiana* (16), *Senecio pectinatus* var. *major* (16), *Carex canescens* (13), *Carex jackiana* (13), *Hierochloe redolens* (11), *Isolepis subtilissima* (11), *Lycopodium scariosum* (9), *Montia fontana* (7), *Oxalis magellanica* (7)

Other Common Taxa: *Asperula gunnii* (62)

Significant Taxa: *Actinotus moorei* (one record 1940)

Weeds: *Hypochaeris radicata* (9), *Cerastium vulgare* (2), *Taraxacum officinale* (2)

Community 2: *Richea continentis – Carpha nivicola – Sphagnum cristatum* wet heathland

Equivalent communities: *Epacris paludasa – Sphagnum cymbifolium* alliance & *Carex gaudichaudiana – Sphagnum cymbifolium* allianee (Costin 1954); *Sphagnum – Richea – Astelia* association (McVean 1969); Bog, Unit 7A (McDougall 1982); Wet alpine heathland, subcommunity 9.4 (Walsh et al. 1984); Type 4a (Helman & Gilmour 1985); Group 12 (Helman et al. 1988). Raised and valley bog (Costin et al. 2000).

Community 2 is widespread through the northern Alps and higher subalps, occurring almost continuously along the Dividing Range from the Brindabella Ranges in the ACT, through Kosciuszko National Park in NSW, and in Victoria from The Cobberas, across the Bogong High Plains with outlying examples on the Mt Buffalo plateau. Occurs mainly in broad valleys, but also in seepage zones on slopes of low relief and along margins of smaller watercourses. Free water, either as pools or as slow-flowing streams, may or may not be present. The community is often a low closed heath dominated by *Baeckea gunniana*, *Epacris paludasa* (and at higher altitudes, *E. glacialis*) and *Richea continentis* with intervening areas dominated by *Sphagnum cristatum* (*S. novo-zelandicum* in pools) and obligately associated herbs (e.g. *Astelia alpina*, *A. psychrocharis*, *Baloskion australe*, *Carex gaudichaudiana*, *Carpha nivicola*, *Celmisia* spp. *Diplaspis nivis*, *Empodisma minus*, *Erigeron paludicola*, *Oreobolus distichus*, *Oschatzia cuneifolia*, *Poa costiniana*). The distinction between valley bogs and raised bogs made by Costin et al. (2000) is not evident in our classification. Whilst vegetation containing *Sphagnum cristatum* in valleys of the Kosciuszko Main Range may appear different from bogs of hillsides, often having fewer, shorter shrubs, they are inseparable floristically. Some of the valley bogs of Costin et al. (2000) may also fall within Community 5 in cases where only small, isolated patches of *Sphagnum cristatum* are present. Community 2 is widespread and locally abundant but has suffered greatly from grazing, trampling and wildfire in recent times. Grazing ceased through most of Kosciuszko National Park in 1958, and on the northern parts of the Bogong High Plains in 1992 and recovery (indicated by dense *Sphagnum cristatum* cover and less entrenched watercourses) has occurred to varying extents through these areas. Where grazing persisted until 2003 (e.g. parts of the Bogong High Plains, Davies Plain and the Nunniong Plateau), degraded bogs are characterised by a less dense *Sphagnum cristatum* cover and entrenched, more rapidly flowering watercourses. Downhill ski developments occur through much of the range of the community and associated impacts such as clearing and modification of local hydrology are apparent in many of these areas.

No. quadrats 68; Native taxa / quadrat 17.4 ± 0.6; Total native taxa 161; Weeds /quadrat 0.1 ± 0.1; Total weed taxa 4

Altitude: 1320 – 1690 – 2100 m.

Diagnostic Taxa: Shrubs *Richea continentis* (100), *Baeckea gunniana* (82), *Epacris paludosa* (68), *Epacris glacialis* (59); **Herbs** *Empodisma minus* (100), *Sphagnum cristatum* (94), *Poa costiniana* (87), *Celmisia* spp. (*pugionifarmis*, sp. aff. *pugioniformis*, *tamentella*) (79), *Carex gaudichaudiana* (75), *Oreobolus distichus* (60), *Astelia alpina* (59), *Carpha nivicola* (53), *Erigeron paludicola* (49), *Diplaspis nivis* (34), *Balaskian australe* (29), *Rytidosperma nivicola* (29), *Aciphylla simplicifolia* (22), *Astelia psychrocharis* (22), *Gentianella muelleriana* (subsp. *muelleriana*, subsp. *alpestris*) (22), *Oschatzia cuneifolia* (22), *Ranunculus gunnianus* (21), *Isolepis aucklandica* (19), *Argyrotegium poliochlorum* (16), *Hydrocotyle algida* (16), *Thelymitra cyanea* (13), *Carex echinata* (6)

Significant Taxa: *Rytidasperma vickeryae*

Weeds: *Acetosella vulgaris* (9), *Festuca rubra* (1), *Holcus lanatus* (1), *Hypochaeris radicata* (1)

Community 3: *Baeckea gunniana – Callistemon pityoides - Sphagnum cristatum* wet heathland

Equivalent communities: *Epacris breviflora – Blindia robusta* alliance (Costin 1954); Wet alpine heathland, subcommunity 9.6 (Walsh et al. 1984); Vegetation Type 4b (Helman & Gilmour 1985); Group 11 (Helman et al. 1988).

Widespread, mostly subalpine, extending from the Brindabella Ranges in the ACT, at scattered localities through Kosciuszko National Park, mostly in the catchments of the Murrumbidgee and Eucumbene Rivers, and in Victoria on the Nunniong Plateau, Dargo High Plains, Baw Baw Plateau, The Cobberas, Mt Buffalo and the Snowy Range south from Mt Howitt, rare on the Bogong High Plains (where generally at low elevations such as Wild Horse Plain). Typically a community of boggy margins of slow-flowing streams, often ± linear and adjacent to *Eucalyptus pauciflora* and/or *E. stellulata* woodlands. Usually at lower elevations than Community 2 but sometimes occurring with and merging into Communities 1 or 2. Examples are usually quite dense heaths and sometimes relatively tall (to c. 1.6 m high), dominated by shrubs such as *Baeckea gunniana*, *Epacris paludasa*, *Richea cantinentis*, *Callistemon pityoides* and *Epacris breviflara*. Herbs are usually rather scant beneath shrubs, but gaps may be herb-rich with species such as *Oreomyrrhis ciliata*, *Poa costiniana*, *Ranunculus pimpinellifolius*, *Celmisia* spp., *Catula alpina*, *Empodisma minus*, *Gonocarpus micranthus*, *Hypericum japonicum* and *Juncus falcatus*. *Sphagnum cristatum* is usually present in wetter areas. A relatively rich weed flora is evidence of less exposed environments than Communities 1 and 2, and probably indicative of greater utilisation (in the recent past) by cattle, particularly when seeking water later in the grazing season as surrounding vegetation becomes drier.

No. quadrats 86; Native taxa / quadrat 25.0 ± 0.9; Total native taxa 264; Weeds /quadrat 1.3 ± 0.2; Total weed taxa 21

Altitude: 1160 – 1465 – 1840 m.

Diagnostic Taxa: Shrubs *Baeckea gunniana* (90), *Epacris paludosa* (73), *Richea continentis* (47), *Callisteman pityoides* (40), *Epacris breviflora* (35), *Epacris gunnii* (28), *Pultenaea tenella* (26), *Hakea microcarpa* (23), *Epacris celata* (7), *Pimelea bracteata* (6); **Herbs** *Empodisma minus* (92), *Carex gaudichaudiana* (77), *Asperula gunnii* (71), *Sphagnum cristatum* (70), *Poa costiniana* (65), *Gonocarpus micranthus* (57), *Luzula modesta* (55), *Celmisia* spp. (*pugioniformis*, sp. aff. *pugioniformis*, *tomentella*) (51), *Ranunculus pimpinellifolius* (47), *Baloskion australe* (44), *Oreomyrrhis ciliata* (43), *Epilobium gunnianum* (35), *Orcobolus distichus* (35), *Hypericum japonicum* (31), *Cotula alpina* (30), *Hydrocotyle algida* (29), *Isolepis crassiuscula* (28), *Erigeron paludicola* (27), *Nertera granadensis* (27), *Juncus falcatus* (24), *Myriophyllum pedunculatum* (24), *Caltha introloba* (22), *Comesperma retusum* (19), *Isolepis aucklandica* (19), *Carex appressa* (17), *Wahlenbergia ceracea* (17), *Carex blakei* (16), *Thelymitra cyanea* (16), *Juncus sandwithii* (14), *Brachyscome obovata* (13), *Drosera peltata* (13), *Isolepis subtilissima* (13), *Carex jackiana* (12), *Chiloglottis* spp. (10), *Oreobolus oxycarpus* (10), *Utricularia monanthos* (8), *Veronica scrpyllifolia* (8), *Hierochloe redolens* (7), *Coprosma moorei* (6)

Significant Taxa: *Deyeuxia talariata*, *Dillwynia palustris*, *Genoplesium turfasum*

Weeds: *Trifolium repens* (26), *Acetosella vulgaris* (16), *Cerastium glomeratum* (14), *Hypochaeris radicata* (14), *Taraxacum officinale* (10), *Cerastium vulgare* (9), *Poa pratensis* (8), *Mimulus moschatus* (6), *Cirsium vulgare* (5), *Prunella vulgaris* (3), *Anthoxanthum odoratum* (2), *Veronica arvensis* (2), *Agrostis capillaris* (1), *Agrostis stolonifera* (1), *Aphanes arvensis* (1), *Bromus hordeaceus* (1), *Conyza bonariensis* (1), *Juncus bufonius* (1), *Phleum pratense* (1), *Trifolium dubium* (1), *Vulpia bromoides* (1)

Community 4: *Epacris* moist heathland

Equivalent communities: *Epacris glacialis* heathland, Unit 7B (McDougall 1982); *Epacris glacialis* heath (Costin et al. 2000).

Many bogs, fens, streams and lakes in the higher parts of the Australian Alps are bordered by a low heathland on mineralised peat soil (Fig. 5). On the Bogong High Plains in Victoria this is invariably dominated by *Epacris glacialis*. On the Main Range of Kosciuszko National Park in NSW the community may be dominated by *Epacris glacialis*, *E. gunnii* or rarely (mostly at lower elevations) *E. petrophila*. Mat forming plants such as *Stackhousia pulvinaris*, *Pentachondra pumila*, *Argyrotegium* spp. and *Oreobolus distichus* are common. Tussock grasses are not abundant although *Poa costiniana* is usually present. Localised trampling damage is evident in examples on the Bogong High Plains, which, up until summer 2004–2005 were accessible to cattle. The community is well-protected and not requiring management action.

No. quadrats 16; Native taxa / quadrat 19.2 ± 1.5; Total native taxa 96; Weeds /quadrat 0.3 ± 0.3; Total weed taxa 4

Altitude: 1650 – 1825 – 2150 m.

Diagnostic Taxa: Shrubs *Pentachondra pumila* (63), *Epacris glacialis* (56), *Pimelea alpina* (56), *Epacris gunnii* (44), *Epacris petrophila* (25); **Herbs** *Poa costiniana* (88), *Celmisia* spp. (*costiniana*, *pugioniformis*, *tomentella*) (81), *Empodisma minus* (81), *Oreobolus distichus* (56), *Ranunculus gunnianus* (56), *Stackhousia pulvinaris* (56), *Erigeron nitidus* (50), *Argyrotegium fordianum* (38), *Gentianella muelleriana* subsp. *alpestris* (25), *Argyrategium paliochlorum* (25), *Ranunculus muelleri* (25), *Rytidosperma nivicola* (25)

Other Common Taxa: *Carex breviculmis* (56), *Craspedia* spp. (*aurantia*, *maxgrayi*) (56), *Rytidosperma nudiflorum* (50)



Fig. 5. *Epacris glacialis* moist heathland (Community 4) beside Pretty Valley Creek on the Bogong High Plains. There is usually a sharp boundary between this community, which is found on humified peat, and those of dry sites on alpine humus soil (in this case, Community 24 in the background). The creek itself is typical of the habitat of Community 9. However, *Myriophyllum pedunculatum* seems to be the only species of that disparate community to occur here.

Significant Taxa: *Euphrasia* sp. 3

Weeds: *Hypochaeris radicata* (13), *Acetosella vulgaris* (6), *Taraxacum officinale* (6), *Trifolium repens* (6)

Community 5: Alpine valley grassland

Equivalent communities: part of *Poa caespitosa – Danthonia nudiflora* alliance (Costin 1954): Sod tussock grassland (Costin et al. 2000).

This community is similar in appearance, habitat and usual dominant (*Poa costiniana*) to Community 14 yet is distinct floristically, having much lower species diversity and containing many species commonly found in wetland vegetation only at higher elevation. It is restricted to Kosciuszko National Park and is especially common beside low-velocity waterways in the high subalpine zone (e.g. Spencers Creek, Guthrie Creek, upper Snowy River).

No. quadrats 9; Native taxa / quadrat 16.8 ± 0.9; Total native taxa 65; Weeds /quadrat 0.6 ± 0.4; Total weed taxa 5

Altitude: 1740 – 1830 – 2010 m.

Diagnostic Taxa: Shrubs *Epacris glacialis* (56); **Herbs** *Poa costiniana* (100), *Craspedia* spp. (*jamesii*) (89), *Empodisma minus* (89), *Aciphylla simplicifolia* (78), *Carex gaudichaudiana* (67), *Gentianella muelleriana* subsp. *alpestris* (67), *Ranunculus gunnianus* (44), *Deyeuxia carinata* (33), *Ranunculus millanii* (33)

Other Common Taxa: *Asperula gunnii* (78), *Celmisia* spp. (56), *Oreomyrrhis eriopoda* (56), *Microseris* sp. 2 (44)

Weeds: *Acetosella vulgaris* (11), *Agrostis capillaris* (11), *Cerastium vulgare* (11), *Festuca rubra* (11), *Taraxacum officinale* (11)

Group II – Damp herbfields, fens & waterways

Community 6: *Lobelia surrepens – Ranunculus millanii* herbfield

Equivalent communities: Pratia depression, Unit 8A & Fen (Bog pool), Unit 8B (McDougall 1982); Damp alpine heathland, subcommunity 10.1 (Walsh et al. 1984); Vegetation Type 9 (Helman & Gilmour 1985).

Lobelia surrepens – Ranunculus millanii herbfield occurs on the Bimberi Range (ACT), northern Kosciuszko National Park and surrounds (e.g. Kiandra, Seventeen Flat, Broadway Plain, McPhersons Plain, Cooleman Plain) and a number of sites of suitable topography in Victoria where locally common (e.g. Bogong High Plains, Mt Buffalo, Dargo High Plains, Snowy Range) but is absent from the Baw Baw Plateau and Lake Mountain. It is a low herbfield that is confined to, and highly characteristic of, seasonally inundated depressions of alpine and high subalpine areas (Fig. 6). There appears to be no convincing explanation for the genesis of these formations. The depressions may be more or less linear and oriented across slopes (i.e. the 'contour trenches' of McElroy (1952)), or they may be nearly circular on almost flat ground. They are underlain by water-retentive soils, often derived from igneous parent material, and filled with water following snow-melt. By early summer they are usually empty of surface water but soils remain moist through the season (sometimes filling again during heavy rains). Representative species include the virtually prostrate species *Lobelia surrepens*, *Ranunculus millanii*, *Gonocarpus micranthus*, *Isolepis montivaga*, *Myriophyllum pedunculatum*, *Stackhousia pulvinaris*, *Lachnagrostis meionectes*. The taller sedge, *Carex gaudichaudiana* is usually present, particularly in deeper sections of the depressions where water tends to persist for longer periods. The very rare species *Lobelia gelida* (Mt Buffalo, Snowy Range) is confined to this community, and *Kelleria laxa* (Bogong High Plains) occurs in this community and adjacent grassland.

No. quadrats 16; Native taxa / quadrat 12.9 ± 1.1; Total native taxa 94; Weeds /quadrat 0.6 ± 0.4; Total weed taxa 10

Altitude: 1090 – 1410 – 1770 m.

Diagnostic Taxa: Herbs *Carex gaudichaudiana* (94), *Ranunculus millanii* (94), *Lobelia surrepens* (88), *Gonocarpus micranthus* (63), *Dichondra repens* (50), *Isolepis montivaga* (44), *Myriophyllum pedunculatum* (38), *Hydrocotyle sibthorpioides* (31), *Lachnagrostis aemula* (19)

Significant Taxa: *Lobelia gelida*, *Kelleria laxa*

Weeds: *Trifolium repens* (15), *Acetosella vulgaris* (10), *Agrostis capillaris* (5), *Agrostis stolonifera* (5), *Cirsium vulgare* (5), *Juncus bufonius* (5), *Poa pratensis* (5), *Rorippa palustris* (5), *Rumex conglomeratus* (5), *Taraxacum officinale* (5)

Community 7: Hypericum japonicum – Ranunculus pimpinellifolius herbfield

Equivalent communities: Nil



Fig. 6. Small depression containing *Lobelia surrepens – Ranunculus millanii* herbfield (Community 6) within *Poa costiniana* dominated grassland (Community 24) at head of Cope Creek on the Bogong High Plains.

In Victoria, Community 7 has been recorded from the Dargo High Plains, Nunniong Plateau and plains south of Mt Hotham, with isolated occurrences near Mt Stirling and The Bluff. In New South Wales recorded from Boggy Plain near Tantangara, Long Plain and Bogong Plain near Mt Jagungal but undoubtedly commonly occurring elsewhere within the subalpine area. It occurs in broad valleys or around seepage zones on flat ground anywhere where soils are relatively deep and permanently sodden (but not inundated), often on sites with basaltic parent material (Fig. 7). Forbs such as *Hypericum japonicum*, *Ranunculus pimpinellifolius*, *Ganocarpus micranthus* and *Epilobium curtisiae* are the usual dominants and form a dense mat of overlapping leaves. Examples are often small (a few m^2). A relatively high weed percentage (particularly *Acetosella vulgaris*, *Cerastium glomeratum*, *Holcus lanatus*, *Trifolium repens*) is indicative of disturbance and relatively benign growing conditions. Many of the sites (at least in Victoria) are still subject to cattle grazing. Sites in New South Wales may be affected by pigs.

No. quadrats 14; Native taxa / quadrat 21.8 ± 2.0; Total native taxa 108; Weeds /quadrat 4.6 ± 0.7; Total weed taxa 18

Altitude: 1180 – 1435 – 1740 m.

Diagnostic Taxa: Herbs *Carex gaudichaudiana* (93), *Hypericum japonicum* (86), *Ranunculus pimpinellifolius* (86), *Cotula alpina* (71), *Juncus falcatus* (71), *Epilobium curtisiae* (57), *Euchiton collinus* (57), *Gonocarpus micranthus* (57), *Brachyscome scapigera* (50), *Hydrocotyle sibthorpioides* (50), *Oreomyrrhis ciliata* (50), *Veronica serpyllifolia* (43), *Dichondra repens* (36), *Isolepis montivaga* (36), *Isolepis subtilissima* (29), *Schoenus calyptratus* (29), *Carex inversa* (21)

Other Common Taxa: *Luzula modesta* (50)

Significant Taxa: *Epilobium willisii*, *Wahlenbergia densifolia*

Weeds: *Trifolium repens* (100), *Taraxacum officinale* (50), *Acetosella vulgaris* (43), *Cerastium glomeratum* (43), *Holcus lanatus* (36), *Cerastium vulgare* (29), *Poa pratensis* (29), *Aphanes arvensis* (21), *Hypochaeris radicata* (21), *Prunella vulgaris* (14), *Vulpia bromoides* (14), *Agrostis capillaris* (7), *Medicago* spp. (7), *Myosotis discolor* (7), *Phleum pratense* (7), *Poa annua* (7), *Trifolium dubium* (7), *Veronica peregrina* (7),

Community 8: Fen

Equivalent communities: *Carex gaudichaudiana* alliance (Costin 1954); *Carex – Drepanocladus* association (McVean 1969); Vegetation Type 6a (Helman & Gilmour 1985); Fen (Costin et al. 2000).

Fens are widespread in valleys and low saddles in Kosciuszko National Park (where extending into the alpine zone) and subalpine valleys of the ACT. In Victoria, where less common, they have been recorded from only the Snowy Range, Mt Buffalo, the Bogong High Plains and Nunniong Plateau. The sedge *Carex gaudichaudiana* is ubiquitous within this community and makes it one of the most immediately recognisable of alpine/subalpine vegetation types. Typically, sites are inundated through most, if not all, summer with water depths up to c. 15 cm. Relatively few other species occur within the closed sedgeland, but in some areas *Brachyscome obovata*, *Carex echinata*, *Deschampsia caespitosa*, *Epilobium gunnianum*, *Isolepis crassiuscula*, *Myriophyllum pedunculatum* etc. may be reasonably common. *Sphagnum cristatum* often occupies any ground raised slightly above the bed of the fen. The weed *Myosotis caespitosa*, although not recorded in quadrats, is abundant at a few sites in Kosciuszko National Park (e.g. Boggy Plain, Ogilvies Plain) and may threaten the integrity of this community.

No. quadrats 16; Native taxa / quadrat 13.6 ± 1.9; Total native taxa 87; Weeds /quadrat 0; Total weed taxa 0

Altitude: 1300 – 1700 – 1920 m.

Diagnostic Taxa: Herbs *Carex gaudichaudiana* (100), *Sphagnum cristatum* (81), *Carpha nivicola* (56), *Oreomyrrhis ciliata* (50), *Epilobium gunnianum* (44), *Isolepis crassiuscula* (38), *Myriophyllum pedunculatum* (38), *Brachyscome obovata* (31), *Carex echinata* (31), *Deschampsia caespitosa* (31), *Juncus falcatus* (25)

Other Common Taxa: *Poa costiniana* (63), *Empodisma minus* (50)

Community 9: Aquatic

Equivalent communities: Vegetation Type 6b (Helman & Gilmour 1985).

Occurs in and beside permanent creeks and in deeper pools along intermittent streams (e.g. Nungar Creek and McPhersons Plain in NSW, Sheep Station Ck and Grassy Creek in the ACT, Baw Baw and Nunniong Plateaus and Bogong High Plains in Victoria) but probably more widespread. It includes both true aquatics with fully submerged (e.g. *Myriophyllum alpinum*), floating (*Nymphoides montana*) or emergent foliage (e.g. *Carex gaudichaudiana*), as well as semi-aquatics capable of growing as submergents for extended periods (e.g. *Lilaeopsis polyantha*, *Neopaxia australasica*, *Ranunculus pimpinellifolius*). Plant cover is sporadic and sometimes only one or a few species will be present. Some trampling of creek edges by horses and, on Nunniong Plateau, degradation by cattle was observed in the vicinity of this community. It is possible however that some sites formerly supporting this community have been degraded to the extent that they are no longer floristically analogous. The weed *Myosotis caespitosa* is locally abundant at the margins of some examples (e.g. Cooleman Plain in Kosciuszko National Park).

No. quadrats: 1 (this community appears to have been sampled in the ACT by Helman & Gilmour (1985), based on the two-way table in that report, but the full quadrat data were unavailable to us).

Altitude: 1000 – c.1600 m.

Common Taxa: Herbs *Brachyscome radicans*, *Carex gaudichaudiana*, *Eleocharis acuta*, *Hydracotyle sibthorpioides*, *Hydrocotyle tripartita*, *Lilaeopsis polyantha*, *Myriophyllum pedunculatum*, *Neopaxia australasica*, *Nymphoides montana*, *Ranunculus amphitrichus*, *Ranunculus pimpinellifolius*

Weeds: *Juncus articulatus*, *Myosotis caespitosa*, *Taraxacum officinale*, *Trifolium repens*



Fig. 7. An example of Community 7 at Long Plain (Kosciuszko National Park). The forb-dominated vegetation bordering the creek contrasts with the tussock-dominated vegetation (Community 30) in the background.

Group III – gravelly pavement herbfields

Community 10: Short alpine herbfield

Equivalent communities: part of *Plantago muelleri – Montia australasica* alliance (Costin 1954); *Oreobolus pumilio* association (McVean 1969); *Caltha* herbland, Unit 10 (McDougall 1982); Short alpine herbfield (Costin et al. 2000).

Short alpine herbfield is common above 1700 m in Kosciuszko National Park (between Ramshead Range and Mt Jagungal) but individual stands are rarely more than 100 m². It is extremely rare in Victoria being confined to a few creeks and snowpatches on the Bogong High Plains. A species-depauperate example of this community occurs on the eastern end of the Baw Baw Plateau. Short alpine herbfield is a sparsely-vegetated, semi-aquatic community of shallow, low-gradient streams (and sometimes shallow lake margins), usually with considerable amounts of exposed rock and coarse gravel (Fig. 8). It is often associated with snowpatches and/or bogs. The small, tough-leaved sedge *Oreobolus pumilio* forms dense low cushions and performs an important function by disrupting water flow which allows more tender herbs (some of very restricted occurrence e.g. *Abrotanella nubigena*, *Deyeuxia affinis*, *Drosera arcturi*, *Parantennaria uniceps*) to take root. *Sphagnum cristatum* (and sometimes *S. novo-zelandicum*) usually occurs at the peripheries. Mat-forming species (*Dichosciadium ranunculaceum*, *Oreomyrrhis pulvinifica*, *Plantago glacialis*, *Plantago muelleri*) may be locally dominant. Some Victorian stands are dominated by *Caltha introloba*. The community appears to be dependent on maintenance of exposed gravelly sites and continuous irrigation. Any disruption to local hydrology may permit the expansion of adjacent communities or incursion of aquatic communities. Because of its frequent proximity to late-melting snow, trampling of this community by sightseers may occur during snowmelt. Although this is rare, we have observed damage to *Oreobolus pumilio* cushions from trampling and it is possible that disruption of rock and gravel by tramping limits opportunities for further establishment by short alpine herbfield species. Whilst monitoring of stands of this community subject to trampling would be worthwhile, the removal of trampling pressure from stands of this very rare community wherever possible would be good management. The relatively high number of species of restricted occurrence in this community makes it a high priority for protection.

No. quadrats 31; Taxa / quadrat 17.0 ± 0.8; Total native taxa 84; Weeds /quadrat 0.0 ± 0.0; Total weed taxa 1

Altitude: 1600 – 1900 – 2200 m.

Diagnostic Taxa: Shrubs *Epacris glacialis* (52); **Herbs** *Oreobolus pumilio* (81), *Caltha introloba* (74), *Carex gaudichaudiana* (74), *Drosera arcturi* (74), *Brachyscome stolonifera* (65), *Poa costiniana* (61), *Rytidosperma nivicola* (61), *Oreomyrrhis pulvinifica* (55), *Diplaspis nivis* (48), *Luzula atrata* (48), *Carpha nivicola* (45), *Schoenus calyptratus* (38), *Myriophyllum pedunculatum* (35), *Oreobolus distichus* (35), *Plantago muelleri* (35), *Deyeuxia affinis* (32), *Carpha alpina* (29), *Parantennaria uniceps* (29), *Plantago glacialis* (29), *Deschampsia caespitosa* (26), *Gentianella muelleriana* subsp. *alpestris* (23), *Isolepis crassiuscula* (23), *Carex hypandra* (19), *Euphrasia collina* subsp. *glacialis* (19), *Craspedia alba* (16), *Dichosciadium ranunculaceum* (13), *Rytidosperma australe* (6)

Significant Taxa: *Deyeuxia affinis*

Weeds: *Agrostis capillaris* (3)

Community 11: *Celmisia sericophylla* herbfield

Equivalent communities: *Celmisia sericophylla* herbland, Unit 11 (McDougall 1982).

Community 11 occurs in spring-fed drainage lines of steep east to south facing slopes within Community 17, around waterfalls and beside creeks. It is restricted to the area between Mt Hotham and Mt Bogong, where it is most commonly found on slopes of the higher peaks (e.g. Mt Hotham, Mt McKay, Mt Nelse, Spion Kopje and Mt Bogong). A single occurrence of *C. sericophylla* on the Snowy Range (some 60 km distant from the nearest population and unsampled in this study) is in similar habitat and represents a depauperate isolated example. *Celmisia sericophylla* commonly forms dense stands amongst rock in flowing water. *Caltha introloba* may also be abundant but other species tend to be scattered and rare. Other frequent species are generally interlopers from adjacent heaths, grasslands or bogs (e.g. *Acaena novae-zelandiae*, *Carex gaudichaudiana*, *Isolepis aucklandica*, *Poa costiniana*, *Richea continentis*). Many examples of this community were severely burnt during the fires of early 2003 and recovery of these has been patchy. It will be several years before it is known if they regenerate to the original community. If they do not, it is possible that up to 50% of the known area of this very restricted community will have been lost or severely modified by these fires. Some of the few examples of the community near Mt Hotham were damaged by ski slope developments in the 1980s. Generally though, owing to the often steep and rocky terrain in which the community occurs, examples are relatively intact. Localised trampling damage may occur from sightseers visiting the last snow, although the threat is probably small at present. Some patches are within the ski resorts of Falls Creek and Mt Hotham and may face future pressures from skiing development.

No. quadrats 5; Native taxa / quadrat 13.0 ± 2.4; Total native taxa 34; Weeds /quadrat 0.6 ± 0.3; Total weed taxa 2

Altitude: 1560 – 1735 – 1820 m.

Diagnostic Taxa: Shrubs *Richea continentis* (80); **Herbs** *Celmisia sericophylla* (100), *Isolepis aucklandica* (100), *Acaena novae-zelandiae* (80), *Agrostis parviflora* (80), *Carex gaudichaudiana* (80), *Caltha introloba* (60), *Luzula acutifolia* subsp. *acutifolia* (60), *Deyeuxia affinis* (40)

Other Common Taxa: *Poa costiniana* (60)

Significant Taxa: *Deyeuxia affinis*

Weeds: *Acetosella vulgaris* (40), *Hypochaeris radicata* (20)

Group IV – snowpatch herbfields

Community 12: Coprosma niphophila – Colobanthus nivicola snowpatch feldmark

Equivalent communities: *Coprosma pumila–Colobanthus benthamianus* alliance (Costin 1954); *Coprosma pumila* association (McVean 1969); *Coprosma-Colobanthus* Feldmark (Costin et al. 2000).

This community is confined to the Kosciuszko Main Range. It occupies the upper parts of east- to south-facing slopes with the longest lasting snow (Fig. 9). Soils are shallow and largely bare. *Coprosma niphophila* may be locally dominant. Plant cover is sparse and diversity low. Plants have low stature and many have a mat or cushion habit. Snowpatch feldmark is extremely rare, occupying a total area of only a few ha in about 10 stands. There are few immediate threats although a decrease in winter snowfall because of global warming may ultimately allow the invasion of species from adjoining communities. Because of the steep, unstable habitat, people are only likely to walk in this community during snow-melt, and then mostly on Mt Kosciuszko where the walking track skirts the snowpatch. However, this is when the community is probably most vulnerable to trampling. An assessment of the impact of trampling in this community (especially on Mt Kosciuszko) would be useful. If tramping were significant, temporary barriers might be erected during snowmelt.

No. quadrats 6; Native taxa / quadrat 15.0 ± 0.7; Total native taxa 29; Weeds /quadrat 0.5 ± 0.3; Total weed taxa 2

Altitude: 2050 – 2100 – 2200.

Diagnostic Taxa: Shrubs *Coprasma niphaphila* (100); **Herbs** *Colobanthus nivicola* (100), *Epilobium tasmanicum* (100), *Neapaxia australasica* (100), *Poa fawcettiae* (100), *Agrostis muelleriana* (83), *Luzula acutifolia* subsp. *nana* (83), *Luzula australasica* subsp. *dura* (83), *Senecio pinnatifolius* var. *alpinus* (83), *Euphrasia collina* subsp. *diversicolor* (67), *Ewartia nubigena* (67), *Ranunculus muelleri* (67), *Carex cephalates* (50), *Argyrotegium mackayi* (50), *Isolepis montivaga* (50), *Ranunculus anemaneus* (50), *Erigeron setosus* (33)

Significant Taxa: *Ranunculus anemoneus*

Weeds: *Acetosella vulgaris* (33), *Hypochaeris radicata* (17)

Community 13: Neopaxia australasica – Ranunculus niphophilus snowpatch herbfield

Equivalent communities: part of *Plantago muelleri – Montia australasica* allianee (Costin 1954); *Plantago muelleri – Conostomum curvirastre* association (McVean 1969).

This is a variable community occurring at the base of high elevation snowpatches (usually adjoining Community 17) (Fig. 10), and copiously irrigated during the extended period of snowmelt. It is apparently confined to Kosciuszko National Park, although there are small areas at the base of the Mt Nelse snowpatch on the Bogong High Plains with floristic affinities. The community is often dominated by *Neopaxia australasica* but *Poa costiniana*, *Carex hypandra*, *Plantago muelleri* and *Ranunculus niphaphilus* may be locally abundant. Trampling of this community by sightseers might occur during snowmelt but we saw no significant damage of this nature during our survey.

No. quadrats 8; Native taxa / quadrat 14.0 ± 1.9; Total native taxa 54; Weeds /quadrat 0.4 ± 0.3; Total weed taxa 2

Altitude: 1920 – 2070 – 2170 m.

Diagnostic Taxa: Herbs *Poa costiniana* (100), *Carex cephalotes* (63), *Neopaxia australasica* (63), *Carex hypandra* (50), *Plantago muelleri* (50), *Polystichum proliferum* (50), *Ranunculus anemaneus* (50), *Ranunculus niphophilus* (50), *Agrostis muelleriana* (38), *Blechnum penna-marina* subsp. *alpina* (38), *Brachyscome nivalis* (38), *Epilobium tasmanicum* (38), *Luzula acutifalia* subsp. *nana* (38), *Oreomyrrhis pulvinifica* (38), *Plantago glacialis* (38), *Cardamine robusta* (25), *Carex canescens* (25)



Fig. 8. Short alpine herbfield (Community 10) in Cope Creek, Bogong High Plains. The community occupies wet, gravelly pavements, often at the base of snowpatches. The dominant in the photo is *Oreobolus pumilio*. The low heathland in the background is *Epacris* moist heathland (Community 4).

Significant Taxa: *Ranunculus anemoneus*

Weeds: *Acetosella vulgaris* (25), *Hypochaeris radicata* (13)

Group V – subalpine valley & fertile grasslands

Community 14: Subalpine valley grassland

Equivalent communities: part of *Poa caespitosa – Danthonia nudiflora* alliance (Costin 1954); Damp alpine heathland, subcommunity 10.3 (Walsh et al. 1984); Group 10 (Helman et al. 1988).

This community is common from Bimberi, Brindabella and Scabby Ranges (ACT) through lower altitude plains within Kosciuszko National Park (Kiandra and Tantangara areas, Mt Selwyn, Tooma/Tumut Divide, Cooleman Plain, Happy Jacks Plain, Currango Plain), but is confined to the more easterly ranges in Victoria (e.g. Mt Wombargo-Cobberas area, Nunniong Plateau, Davies Plain, Dinner Plain). It is a grassland or occasionally open heathland confined to broad valley floors and seepage areas on gentle slopes (Fig. 11). Dominant species vary between localities, but common components include the shrubs *Epacris breviflora*, *E. gunnii*, *Hakea microcarpa* and herbaceous species such as *Austrofestuca hookeriana*, *Baloskion australe*, *Carex gaudichaudiana*, *Empodisma minus*, *Poa costiniana* (the usual dominant) and *Stylidium montanum*. Soils are typically sodden humified peats. Some sites in NSW (Kiandra area) and Victoria (near Mt Wombargo) are subject to excavation by feral pigs, causing these sites to dry and making them vulnerable to weed invasion. Cattle grazing occurred until recently on most sites supporting this community on the Nunniong Plateau and Davies Plain in Victoria. Both these factors are reflected in the relatively high weed diversity.

No. quadrats 70; Native taxa / quadrat 25.9 ± 1.1; Total native taxa 251; Weeds /quadrat 2.1 ± 0.2; Total weed taxa 20

Altitude: 1020 – 1355 – 1680 m.

Diagnostic Taxa: Shrubs *Epacris gunnii* (43), *Epacris breviflora* (40), *Hakea microcarpa* (39), *Baeckea utilis* (20), *Leptospermum myrtifolium* (7), *Leucopogon pilifer* (7); **Herbs** *Poa costiniana* (76), *Empodisma minus* (66), *Baloskion australe* (64), *Luzula modesta* (61), *Carex gaudichaudiana* (59), *Austrofestuca hookeriana* (56), *Gonocarpus micranthus* (51), *Hypericum japonicum* (51), *Oreomyrrhis ciliata* (50), *Craspedia* spp. (*crocata*, *aurantia*) (49), *Stylidium* spp. (46), *Brachyscome scapigera* (39), *Epilobium gunniannm* (37), *Cotula alpina* (36), *Epilobium billardierianum* (34), *Ranunculus pimpinellifolius* (34), *Stellaria angustifolia* (31), *Hydrocotyle algida* (30), *Hypoxis hygrometrica* (30), *Schoenus apogon* (26), *Wahlenbergia ceracea* (26), *Arthropodium milleflorum* (23), *Hydrocotyle sibthorpioides* (23), *Senecio gunnii* (23), *Velleia montana* (23), *Brachyscome obovata* (20), *Ranunculus collinus* (20), *Juncus falcatus* (19), *Poa clivicola*



Fig. 9. The steep east-facing slope between Mt Lee and Northcote Pass (Kosciuszko Main Range) supports Community 12 (the upper, bare, rocky portions) and Community 17 (dominated by *Celmisia costiniana* in the upper portions and *Poa fawcettiae* below).

(19), *Carex blakei* (17), *Anstrodanthonia laevis* (16), *Cardamine astoniae* (14), *Dichelachne micrantha* (14), *Isolepis crassiuscula* (14), *Neopaxia australasica* (14), *Plantago varia* (14), *Ranunculus millanii* (14), *Utricularia monanthos* (14), *Agrostis hiemalis sens. lat.* (13), *Carex jackiana* (13), *Comesperma retusum* (13), *Asperula pusilla* (11), *Deyeuxia gunniana* (11), *Enchiton involucratus* (11), *Oreobolus oxycarpus* (11), *Oscluatzia cuneifolia* (11), *Poa labillardierei* (11), *Viola fuscoviolacea* (11), *Lachnagrostis aemula* (10), *Ranunculus lappaceus* (10), *Euphrasia caudata* (9), *Deyeuxia innominata* (7), *Juncus brevibracteus* (7), *Juncus phaeanthus* (7).

Other Common Taxa: *Asperula gunnii* (63)

Significant Taxa: *Dillwynia palustris, Xeroclrysum palustre*

Weeds: *Trifolium repens* (36), *Hypochaeris radicata* (31), *Taraxacum officinale* (23), *Acetosella vulgaris* (19), *Holcus lanatus* (17), *Anthoxanthum odoratum* (9), *Myosotis caespitosa* (9), *Cerastium vulgare* (7), *Trifolium dubium* (6), *Cerastium glomeratum* (3), *Crepis capillaris* (3), *Achillea millefolium* (1), *Agrostis capillaris* (1), *Centaurium erythraea* (1), *Cirsium vulgare* (1), *Mimulus moschatus* (1), *Prunella vulgaris* (1), *Salix cinerea* (1), *Salix* x *rubens* (1), *Verbascum thapsus* (1)

Community 15: Snowy Range Grassland

Equivalent communities: Alpine grassland, subcommunities 7.1 & 7.2 (Walsh et al. 1984).

This community is characteristic of plains on the Snowy Range between Mt Wellington and Mt Howitt, with isolated occurrences on Mt Stirling, Mt Buffalo and near The Bluff. It is a tussock grassland to open heathland of broad concave plains, usually surrounded by *Eucalyptus pauciflora* woodlands and presumably treeless from the frost hollow effect. Topographically higher examples tend to contain a larger proportion of shrubby species indicating the ecological link of this community between dry heaths (typically dominated by *Hovea montana* and/or *Leucopogon hookeri*) and wet heaths (with *Epacris breviflora*, *E. celata* dominant) or bogs along the valley floor. Dominant grasses are *Poa costiniana*, *Poa fawcettiae*, with sedges *Carex gaudichaudiana* and *Carex breviculmis* and rushes *Empodisma minus* and *Luzula modesta* usually present. A variety of forbs is common (e.g. *Ranunculus* spp., *Brachyscome decipiens*, *Hypericum japonicum*, *Gonocarpus micranthus*). Many sites supporting this community on the southern part of the Snowy Range were severely burnt by wildfire in 1998. Prior to then cattle grazing had occurred through most of the area. Recovery of these sites has proceeded well to the extent that vegetated



Fig. 10. Community 13 (*Neopaxia australasica – Ranunculus niphophilus* snowpatch herbfield) is found at the bases of persistent snowpacks – this example on the east face of Mt Townsend. Plants receive abundant water from snowmelt for most of the growing season.

cover, structure and composition of at least dominant species now approaches that of pre-fire condition. The Mt Buffalo site at Hospice Plain was burnt in the 2003 wildfires and recovery of this nearly pure grassland is proceeding well with most species recorded pre-fire having reappeared by February 2005.

No. quadrats 32; Native taxa / quadrat 27.7 ± 1.0; Total native taxa 136; Weeds /quadrat 2.1 ± 0.3; Total weed taxa 11

Altitude: 1260 – 1525 – 1760 m.

Diagnostic Taxa: Shrubs *Hovea montana* (47), *Pultenaea tenella* (34), *Epacris breviflora* (28); **Herbs** *Ranunculus graniticola* (97), *Asperula gunnii* (88), *Carex breviculmis* (84), *Brachyscome decipiens* (81), *Viola betonicifolia* (78), *Cotula alpina* (72), *Poa fawcettiae* (72), *Microseris* sp. 2 (69), *Scleranthus biflorus* (66), *Empodisma minus* (63), *Luzula modesta* (59), *Carex gaudichaudiana* (56), *Celmisia* spp. (56), *Leptorhynchos squamatus* subsp. *alpinus* (56), *Ajuga australis* (53), *Plantago antarctica* (47), *Brachyscome scapigera* (44), *Ranunculus gunnianus* (44), *Gonocarpus micranthus* (41), *Stackhousia pulvinaris* (38), *Hypericum japonicum* (34), *Prasophyllum* spp. (34), *Trachymene humilis* (34), *Agrostis hiemalis* sens. lat. (31), *Agrostis venusta* (31), *Gentianella muelleriana* subsp. *willisiana* (28), *Schoenus calyptratus* (28), *Luzula flaccida* (25), *Velleia montana* (25), *Caesia alpina* (22), *Argyrotegium mackayi* (22), *Euchiton traversii* (22), *Viola fuscoviolacea* (22), *Oplioglossum lusitanicum* (13)

Other Common Taxa: *Craspedia* spp. (66), *Poa costiniana* (53), *Oreomyrrhis eriopoda* (41), *Pimelea alpina* (41), *Rytidosperma nudiflorum* (41)

Weeds: *Acetosella vulgaris* (50), *Trifolium repens* (44), *Cerastium vulgare* (28), *Hypochaeris radicata* (25), *Taraxacum officinale* (19), *Aphanes arvensis* (16), *Poa pratensis* (9), *Trifolium dubium* (6), *Veronica arvensis* (6), *Achillea millefolium* (3), *Cerastium glomeratum* (1)

Community 16: Victorian subalpine basalt grassland

Equivalent communities: Subalpine grassland, Unit 9 (McDougall 1982); Alpine grassland, subcommunity 7.3 (Walsh et al. 1984).

A grassland usually on soils derived from basalt which imparts to the soil high water retention properties indicated by the presence of a number of species characteristic of bogs and bog margins not usually encountered in grasslands (e.g. *Hypericum japonicum, Carex gaudichaudiana, Epilobium curtisiae, Velleia montana*). Examples of this community may be extensive, occupying many continuous hectares (e.g. Dargo High Plains, Nunniong Plateau, Bennison High Plains, Dinner Plains). Virtually all sites were grazed by stock prior to cessation of licensed grazing in 2005. Some are on enclaves of private land within the Alpine National Park and will continue to be grazed. The grazing history is probably responsible for the relatively high weed diversity. Local severe trampling damage is evident at Lankeys Plain and there is considerable vehicle-based recreational use around Gow Plain where some of the most extensive stands of the threatened sedge *Carex paupera* occur. The weeds *Viola arvensis* and *Potentilla recta* are largely confined to this community in the Victorian high country, probably escaped from gardens in adjacent freehold land. A program to halt their progress in Victoria is warranted.

No. quadrats 36; Native taxa / quadrat 25.3 ± 1.1; Total native taxa 149; Weeds /quadrat 4.9 ± 0.3; Total weed taxa 21

Altitude: 1200 – 1465 – 1620 m.

Diagnostic Taxa: Herbs *Poa hiemata* (86), *Epilobium billardierianum* (69), *Luzula modesta* (69), *Oreomyrrhis eriopoda* (64), *Hypericum japonicum* (61), *Brachyscome scapigera* (58), *Cotula alpina* (58), *Scleranthus biflorus* (58), *Brachyscome decipiens* (56), *Geranium antrorsum* (53), *Austrodanthonia pilosa* (50), *Carex gaudichaudiana* (50), *Craspedia* spp. (50), *Carex hebes* (44), *Ajuga australis* (42), *Dichondra repens* (42), *Diuris monticola* (42), *Oplioglossum lusitanicum* (42), *Oxalis exilis* (42), *Argyrotegium mackayi* (39), *Ranunculus eichlerianus* (39), *Gonocarpus micranthus* (33), *Prasophyllum* spp. (33), *Acaena ovina* (28), *Carex appressa* (28), *Velleia montana* (28), *Ranunculus lappaceus* (25), *Euchiton collinus* (22), *Plantago antarctica* (22), *Solenogyne* spp. (22), *Asperula scoparia* (17), *Caesia alpina* (17), *Deyeuxia crassiuscula* (17), *Epilobium curtisiae* (17), *Juncus australis* (17), *Plantago varia* (17), *Agrostis australiensis* (14), *Agrostis muelleriana* (14), *Carex inversa* (13), *Agrostis aemula* (11), *Epilobium hirtigerum* (11), *Myosotis australis* (11)

Other Common Taxa: *Carex breviculmis* (69), *Asperula gunnii* (50), *Poa costiniana* (44), *Viola betonicifolia* (42), *Ranunculus graniticola* (40)

Significant Taxa: *Carex paupera, Wahlenbergia densifolia*

Weeds: *Trifolium repens* (97), *Acetosella vulgaris* (69), *Cerastium glomeratum* (44), *Hypochaeris radicata* (42), *Taraxacum officinale* (42), *Aphanes arvensis* (25), *Cerastium vulgare* (25), *Poa pratensis* (22), *Phleum pratense* (14), *Trifolium dubium* (8), *Veronica peregrina* (8), *Viola arvensis* (8), *Vulpia bromoides* (8), *Cirsium vulgare* (6), *Veronica arvensis* (6), *Myosotis discolor* (4), *Agrostis capillaris* (3), *Holcus lanatus* (3), *Lotus corniculatus* (3), *Medicago* spp. (3), *Potentilla recta* (3)

Group VI – closed alpine grasslands

Community 17: Poa fawcettiae – Celmisia costiniana snowpatch grassland

Equivalent communities: part of *Celmisia longifolia – Poa caespitosa* alliance (Costin 1954); *Celmisia longifolia* association (McVean 1969); Diuturnal snowpatch, Unit 6 (McDougall 1982).

In New South Wales this community is largely restricted to the Koseiuszko Main Range and a few of the higher peaks elsewhere in Kosciuszko National Park (e.g. Mt Jagungal, Dicky Cooper Bogong). In Victoria, it is confined to the higher parts of the Bogong High Plains (Mt Bogong, Mt Nelse, Spion Kopje), Mt Hotham and Mt Feathertop. This grassland or open-herbfield community is characteristic of sheltered sites that accumulate snow during winter and retain snow often until mid or late summer. Typically sites are steep, often ± concave and of south-easterly aspect (Fig. 9). The growing season is short due to the relatively brief exposure to sun, and the number of species able to flourish in these conditions is relatively low. Plants in this community require adaptations to survive the potentially erosive forces of melting snow on steep slopes and to best utilise the shortened period of insolation – consequently rhizomatous and rosetted perennials dominate (e.g. *Carex hebes, C. breviculmis, Celmisia costiniana, Argyrotegium* spp.). The tough-leaved grasses *Poa fawcettiae* and *Rytidosperma nudiflorum* are particularly abundant. The steepness of these sites, and the volume of water irrigating them during thaw of the snow pack renders them susceptible to soil loss following disruption of the vegetated cover. The evidence of damage from cattle tramping is still obvious in many stands on the Bogong High Plains. Localised, minor trampling damage probably still occurs as a result of people visiting snowpatches in summer as the last snow melts. At this time, the soils are still saturated and vulnerable to trampling.

No. quadrats 28; Native taxa / quadrat 11.4 ± 1.0; Total native taxa 85; Weeds /quadrat 0.8 ± 0.1; Total weed taxa 2

Altitude: 1710 – 1880 – 2160 m.

Diagnostic Taxa: Herbs *Poa fawcettiae* (100), *Carex hebes* (93), *Celmisia costiniana* (75), *Rytidosperma nudiflorum* (57), *Erigeron nitidus* (32), *Argyrotegium mackayi* (32), *Euphrasia collina* subsp. *diversicolor* (21), *Ewartia nubigena* (21)

Other Common Taxa: *Carex breviculmis* (43)

Significant Taxa: *Argyrotegium nitidulum*, *Ranunculus anemonens*

Weeds: *Acetosella vulgaris* (64), *Hypochaeris radicata* (11)

Community 18: Poa fawcettiae – Uncinia sulcata grassland

Equivalent communities: part of *Celmisia longifolia – Poa caespitosa* alliance (Costin 1954); Part of the Tall Alpine Herbfield of Costin et al. (2000).

Community 18 is a dense grassland with low species diversity, which occurs on shallow soil interspersed with large granite tors. It is locally common on mountain tops of the Main Range between Mt Townsend and Mt Twynam, and further north on Mt Jagungal. The community is dominated by *Poa fawcettiae*, which often has a cover close to 100% but species such as *Uncinia sulcata* and *Poa saxicola* may be locally abundant. It is floristically similar to Community 17 and often intergrades with it on the eastern side of ridges and summits. It can be distinguished by its position in the landscape (not occurring under late-lying snowpacks) and less cover of common snowpatch species such as *Carex hebes* and *Rytidosperma nudiflorum*. Small examples of Community 22, often dominated by *Pentachondra pumila*, may occur within Community 18.

No. quadrats 7; Native taxa / quadrat 11.3 ± 1.5; Total native taxa 31; Weeds /quadrat 0.1; Total weed taxa 1

Altitude: 1970 – 2090 – 2200 m.

Diagnostic Taxa: Herbs *Carex hebes* (100), *Poa fawcettiae* (100), *Rytidosperma nudiflorum* (86), *Craspedia costiniana* (71), *Senecio pinnatifolius* var. *alpinus* (71), *Uncinia sulcata* (71), *Poa saxicola* (57)

Other Common Taxa: *Carex breviculmis* (86), *Microseris* sp. 2 (57), *Lycopodium fastigiatum* (43)

Weeds: *Acetosella vulgaris* (14)

Community 19: Chionochloa frigida grassland

Equivalent communities: part of *Celmisia longifolia – Poa caespitosa* alliance (Costin 1954); *Danthonia frigida* association (McVean 1969); part of the Tall Alpine Herbfield of Costin et al. (2000).

Community 19 is a grassland with a sparse to dense cover of the tall grass *Chionochloa frigida*. *Poa fawcettiae* may be locally dominant. This community is found on steep slopes with shallow soil at high altitudes on the Main Range of Kosciuszko National Park, from Ramshead Range to Dicky Cooper Bogong. It is especially well-developed on the south- to west-facing slopes of Lake Albina and Carruthers Peak. The community is well protected and under no obvious threat at present. The usual dominant, *Chionochloa frigida*, has apparently expanded its range greatly since the cessation of grazing by domestic animals (Costin et al. 2000).

No. quadrats 12; Native taxa / quadrat 16.8 ± 1.3; Total native taxa 88; Weeds /quadrat 0.6 ± 0.1; Total weed taxa 3

Altitude: 1780 – 1940 – 2110 m.

Diagnostic Taxa: Shrubs *Pimelea alpina* (67); **Herbs** *Chionochloa frigida* (83), *Poa fawcettiae* (83), *Aciphylla glacialis* (58), *Lycopodium fastigiatum* (58), *Carex hebes* (50), *Celmisia costiniana* (50), *Ranunculus anemoneus* (50), *Gonocarpus montanus* (42), *Helichrysum scorpioides* (42), *Polystichum proliferum* (42), *Schizeilema fragoseum* (25)

Other Common Taxa: *Viola betonicifolia* (58), *Carex breviculmis* (50), *Microseris* sp. 2 (42), *Oreomyrrhis eriopoda* (42), *Rytidosperma nudiflorum* (42)

Significant Taxa: *Ranunculus anemoneus*

Weeds: *Acetosella vulgaris* (42), *Hypochaeris radicata* (8), *Taraxacum officinale* (8)

Group VII – high altitude grasslands & open heathlands

Community 20: Short turf snowpatch grassland

Equivalent communities: Short turf snowpatch, Unit 5D (McDougall 1982).

Short turf snowpatch grassland is restricted to the Bogong High Plains, where it occurs on sheltered, east to south-facing slopes where snow usually persists until late spring. Although mostly found below the upper treeline, small patches may be found in alpine areas within Community 17 (e.g. Mt Nelse). Short turf snowpatch grassland is characterised by the scarcity of tussocks grasses and shrubs, the low stature of the dominant herbs present (usually *Carex hebes*, *Poa hothamensis* and *Rytidosperma nudiflorum*) and a carpet of mosses (mostly *Polytrichum* spp.) in the gaps between the herbs (Fig. 12). *Trachymene humilis* subsp. *brevicaule* and *Argyrotegium* spp. (*A. fordianum*, *A. mackayi*, *A. nitidulum*) sometimes form large mats within the turf. Most stands are small (usually only a few 100 m^2). Many contain young plants of *Grevillea australis* and *Phebalium squamulosum*, species favoured by the occurrence of bare ground (Wahren et al. 2001). A change from subalpine snowpatch grassland to open heathland (Community 26) seems to be occurring in some cases, probably initiated by past grazing by cattle, which was particularly intense in this community. This transition may also be a consequence of recent elevated temperatures leading to shorter persistence of the snow pack

No. quadrats 13; Native taxa / quadrat 17.4 ± 1.5; Total native taxa 58; Weeds /quadrat 2.1 ± 0.2; Total weed taxa 5

Altitude: 1670 – 1755 – 1850 m.

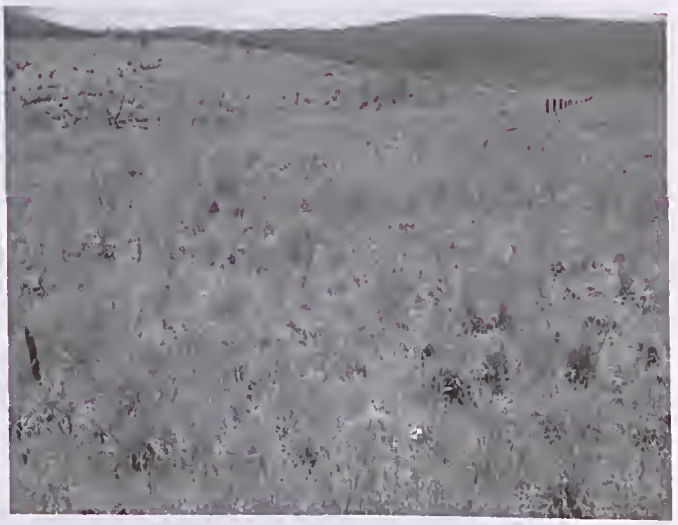


Fig. 11. Community 14. (Subalpine valley grassland) occupies subalpine valley floors throughout the northern portion of the Australian Alps. It is often dominated by large tussocks of *Poa costiniana* (as in this example at Rocky Plains near Kiandra), although shrubs such as *Epacris breviflora* and *E. gunnii* may be frequent or co-dominant. The example shown was thoroughly burnt in the 2003 fires. Twelve months later (as shown) most species had regenerated and cover of the dominant was approaching pre-fire levels.

Diagnostic Taxa: Shrubs *Olearia frostii* (54), *Pimelea axiflora* subsp. *alpina* (54); **Herbs** *Carex hebes* (100), *Acaena novae-zelandiae* (92), *Poa hothamensis* (92), *Oreomyrrhis eriopoda* (85), *Rytidosperma nudiflorum* (85), *Viola betonicifolia* (85), *Plantago euryphylla* (77), *Scleranthus biflorus* (62), *Argyrotegium fordianum* (46), *Leptinella filicula* (38), *Trachymene humilis* subsp. *brevicaule* (23)

Other Common Taxa: *Celmisia* spp. (69), *Asperula gunnii* (54), *Luzula* spp. (54), *Microseris* sp. 2 (54)

Significant Taxa: *Argyrotegium nitidulum*

Weeds: *Acetosella vulgaris* (100), *Hypochaeris radicata* (77), *Trifolium repens* (16), *Agrostis capillaris* (8), *Cerastium vulgare* (8)

Community 21: Bogong High Plains *Hovea montana* heathland

Equivalent communities: Hovea basaltic heathland, Unit 3B (McDougall 1982).

Low heathland dominated by *Hovea montana* on the Bogong High Plains is common on lee slopes on the basalt country west of Pretty Valley and in the Hotham area. It is also prominent in the vicinity of Mt Fainter, where it has been dissected by numerous cattle tracks. This community is characterised by the dominance of *Hovea montana* and the rarity of the shrubs and tussock grasses of most dry communities elsewhere on the Bogong High Plains. Herb cover is variable, perhaps depending on the cover of *Hovea montana*. The large stands on Mt Fainter, which have been severely damaged by trampling of cattle, occur on lee slopes where snow persists in spring. It seems likely that these and perhaps other examples were once Community 20.

No. quadrats 10; Native taxa / quadrat 21.4 ± 1.5; Total native taxa 63; Weeds /quadrat 1.8 ± 0.3; Total weed taxa 4

Altitude: 1680 – 1755 – 1840 m.

Diagnostic Taxa: Shrubs *Hovea montana* (100), *Melicytus* sp. aff. *dentatus* (50), *Olearia brevipedunculata* (50), *Olearia frostii* (40); **Herbs** *Carex breviculmis* (100), *Viola betonicifolia* (100), *Asperula gunnii* (90), *Poa hothamensis* (90), *Acaena novae-zelandiae* (70), *Brachyscome decipiens* (70), *Oreomyrrhis eriopoda* (70), *Scleranthus biflorus* (70), *Carex hebes* (60), *Ranunculus victoriensis* (60), *Plantago euryphylla* (50), *Poa hiemata* (50), *Brachyscome rigidula* (40), *Asperula pusilla* (30)

Other Common Taxa: *Microseris* sp. 2 (70), *Poa costiniana* (60), *Rytidosperma nudiflorum* (60), *Celmisia* spp. (50), *Leucopogon* spp. (*hookeri, montanus*) (50)

Weeds: *Acetosella vulgaris* (70), *Hypochaeris radicata* (40), *Cerastium glomeratum* (10), *Taraxacum officinale* (10)

Community 22: Poa fawcettiae – Euphrasia collina grassland

Equivalent communities: part of *Celmisia longifolia – Poa caespitosa* alliance (Costin 1954); Part of the *Celmisia–Poa* tall alpine herbfield (Costin et al. 2000).

This grassland occurs on sites of low relief with deep soils (e.g. saddles and stream heads) between the Main Range and Mt Jagungal in Kosciuszko National Park. It is generally dominated by *Poa fawcettiae*, although *P. hiemata* and *Pentachondra pumila* may be locally dominant. Species diversity is usually high (compared with other communities at similar elevation). The community is distinguished from other grasslands on the Main Range included in the *Celmisia – Poa* tall alpine herbfield of Costin et al. (2000) by inter-tussock spaces, which contain a large range of herbaceous species. Tall shrubs are rare, although cycles of shrub and grass dominance (as described by Williams (1992) for similar communities on the Bogong High Plains) may be occurring as Community 22 is floristically similar to Community 23 (an open heathland), with which it occurs. Examples of this community occur in ski resorts and may be affected by development. The largest patches can be found in the headwaters of the Snowy River, where they are well protected and not under threat.

No. quadrats 30; Native taxa / quadrat 20.1 ± 0.8; Total native taxa 95; Weeds /quadrat 0.9 ± 0.1; Total weed taxa 4

Altitude: 1740 – 1985 – 2190 m.

Diagnostic Taxa: Shrubs *Pimelea alpina* (60), *Leucopogon montanus* (50), *Pentachondra pumila* (47); **Herbs** *Craspedia* spp. (*aurantia, costiniana, maxgrayi*) (100), *Celmisia* spp. (*costiniana, pugioniformis*) (97), *Carex breviculmis* (90), *Poa fawcettiae* (87), *Rytidosperma nudiflorum* (87), *Oreomyrrhis eriopoda* (70), *Microseris* sp. 2 (67), *Prasophyllum* spp. (67), *Euphrasia collina* subsp. *diversicolor* (63), *Senecio pinnatifolius* var. *alpinus* (63), *Trisetum spicatum* (57), *Viola betonicifolia* (50), *Gentianella muelleriana* subsp. *alpestris* (43), *Aciphylla glacialis* (40), *Erigeron nitidus* (30), *Luzula alpestris* (30), *Poa saxicola* (30), *Argyrotegium fordianum* (27), *Argyrotegium nackayi* (23), *Australopyron velutinum* (20), *Deyeuxia carinata* (17), *Argyrotegium nitidulum* (10)

Significant Taxa: *Argyrotegium nitidulum*

Weeds: *Acetosella vulgaris* (63), *Hypochaeris radicata* (17), *Agrostis capillaris* (3), *Festuca rubra* (3)

Community 23: Grevillea australis – Nematolepis ovatifolia open heathland

Equivalent communities: part of Heath Formation (Costin et al. 2000).

This community is scattered and common on the dry slopes of the Main Range between Dead Horse Gap (near Thredbo) and Mt Jagungal. It occurs on less exposed sites with deeper soil profiles than Community 46 but may intergrade with it. Floristically, it appears to be intermediate between Communities 22 and 46. Community 23 is usually dominated by low shrubs of *Grevillea australis* and *Nematolepis ovatifolia* but other shrubs such as *Hovea montana*, *Kunzea muelleri* and *Oxylobium ellipticum* may be locally abundant. Shrub cover is often sparse but even where it is almost complete the cover and diversity of herbs is high. The ground layer is usually dominated by *Poa hiemata* but *P. fawcettiae* may also be abundant. Some examples are threatened by skiing development and localised trampling by tourists. The community overall is, however, perhaps the most common type of vegetation on the Main Range and is not considered under threat.

No. quadrats 18; Native taxa / quadrat 22.8 ± 1.4; Total native taxa 98; Weeds /quadrat 0.8 ± 0.1; Total weed taxa 2

Altitude: 1600 – 1835 – 2030 m.

Diagnostic Taxa: Shrubs *Grevillea australis* (72), *Pimelea alpina* (67), *Nematolepis ovatifolia* (61), *Oxylobium ellipticum* (33); **Herbs** *Carex breviculmis* (94), *Celmisia* spp. (*costiniana, pugioniformis*) (89), *Craspedia* spp. (*aurantia, jamesii*) (89), *Poa hiemata* (72), *Oreomyrrhis eriopoda* (67), *Rytidosperma nudiflorum* (56), *Aciphylla simplicifolia* (44), *Lycopodium fastigiatum* (39)

Other Common Taxa: *Microseris* sp. 2 (61), *Ranunculus graniticola* (50), *Asperula gunnii* (44), *Scleranthus biflorus* (44)

Significant Taxa: *Argyrotegium nitidulum*

Weeds: *Acetosella vulgaris* (56), *Hypochaeris radicata* (22)

Community 24: Bogong High Plains *Poa costiniana* grassland

Equivalent communities: *Poa costiniana* tussock grassland, Unit 5A (McDougall 1982).

Grassland dominated by *Poa costiniana* is common in areas underlain by basalt on the Bogong High Plains (e.g. Basalt Hill, Mt Jim, Mt Loch) and is occasional on other strata (e.g. on soils overlying gneiss and schist in the upper Cope Creek catchment). The community is characterised by the dominance of *Poa costiniana* and scarcity of other species (especially shrubs), although diversity is relatively high for grasslands at this altitude. Weeds are generally more abundant in this grassland than in others on the Bogong High Plains. Community 24 usually contains shallow depressions (Community 6: *Lobelia surrepens – Ranunculus millanii* herbfield), the pools filling with water during snow melt and after heavy rain (Fig. 6). This community and Community 6 support the only Australian occurrences of *Kelleria laxa*, otherwise confined to New Zealand.

No. quadrats 23; Native taxa / quadrat 21.2 ± 1.2; Total native taxa 92; Weeds /quadrat 2.7 ± 0.3; Total weed taxa 8

Altitude: 1570 – 1730 – 1840 m.

Diagnostic Taxa: Shrubs *Melicytus* sp. aff. *dentatus* (48), *Exocarpos nanus* (26); **Herbs** *Poa costiniana* (100), *Carex breviculmis* (91), *Oreomyrrhis eriopoda* (87), *Microseris* sp. 2 (70), *Rytidosperma nudiflorum* (70), *Acaena novae-zelandiae* (61), *Plantago euryphylla* (57), *Poa hiemata* (57), *Brachyscome decipiens* (52), *Ranunculus victoriensis* (52), *Ajuga australis* (39), *Leptinella filicula* (39), *Colobanthus affinis* (35), *Epilobium billardierianum* (35), *Erigeron nitidus* (35), *Poa hothamensis* (35), *Cardamine lilacina* (30), *Scleranthus singuliflorus* (30), *Veronica serpyllifolia* (30), *Asperula pusilla* (26), *Isolepis montivaga* (26), *Ranunculus muelleri* (26)

Other Common Taxa: *Aspernla gunnii* (57), *Viola betonicifolia* (52), *Scleranthus biflorus* (48)

Significant Taxa: *Kelleria laxa*

Weeds: *Acetosella vulgaris* (87), *Trifolium repens* (61), *Taraxacum officinale* (48), *Cerastium glomeratum* (30), *Hypochaeris radicata* (22), *Agrostis stolonifera* (9), *Veronica arvensis* (9), *Cerastium vulgare* (4)

Community 25: Bogong High Plains *Poa hiemata* grassland

Equivalent communities: *Poa hiemata* tussock grassland, Unit 5B & Tussock grassland / mat heathland, Unit 5C (McDougall 1982)

This is one of the most common communities on the Bogong High Plains. It is found from Mt Hotham to Mt Bogong in saddles, low ridges and valley heads with deep soils, mainly originating from metamorphic parent material (Fig. 13). The largest example is on the flat floor of Pretty Valley. Whilst species richness is comparable with Community 24, the abundance of most forbs is much greater in examples of Community 25 and the cover of *Poa* species is less. *Poa hiemata* is the usual dominant. In a few places (e.g. Pretty Valley and Mt Nelse), *Pentachondra pumila* is the dominant and *Poa hiemata* is rare or absent (and replaced as the most abundant grass by *Poa fawcettiae*). Whilst this variant was recognised as distinct by McDougall (1982), quadrats of this nature did not aggregate in the current study. Community 25 often occurs in a mosaic with Community 26 (open heathland). Cyclical changes between these two communities may occur (Williams 1992, McDougall 2003). The area covered by Community 25 declined in the Cope Creek area between 1936 and 1980 (McDougall 2003) and in the Watchbed Creek area between 1961 and 1994 (Bruce et al. 1999).

No. quadrats 77; Native taxa / quadrat 20.7 ± 0.6; Total native taxa 110; Weeds /quadrat 1.6 ± 0.1; Total weed taxa 7



Fig. 12. The short turf snowpatch grassland (Community 20) occurs on lee slopes of low relief on the Bogong High Plains – the example shown (in the background) is on Mt Cope. It is easily distinguished from other grasslands (such as Community 25 in the foreground) by the absence of tussock grass species.

Altitude: 1380 – 1690 – 1930 m.

Diagnostic Taxa: Shrubs *Pimelea alpina* (55), *Asterolasia trymalioides* (43), *Melicytus* sp. aff. *dentatus* (38), *Pentachondra pumila* (17); **Herbs** *Carex breviculmis* (95), *Poa hiemata* (84), *Asperula gunnii* (75), *Rytidosperma nudiflorum* (75), *Oreomyrrhis eriopoda* (74), *Scleranthus biflorus* (73), *Luzula modesta* (71), *Ranunculus victoriensis* (69), *Brachyscome decipiens* (66), *Senecio pinnatifolius* var. *alpinus* (64), *Craspedia* spp. (*coolaminica, jamesii*) (61), *Celmisia* spp. (*costiniana, pugioniformis*) (60), *Plantago euryphylla* (60), *Trisetum spicatum* (56), *Microseris* sp. 2 (53), *Leptorhynchos squamatus* subsp. *alpinus* (47), *Poa fawcettiae* (47), *Ajuga australis* (42), *Cardamine lilacina* (39), *Argyrotegium fordianum* (38), *Carex hebes* (36), *Scleranthus singuliflorus* (30), *Australopyron velutinum* (27), *Leptinella filicula* (27), *Colobanthus offinis* (25), *Prasophyllum* spp. (25), *Erigeron bellidioides* (22), *Erigeron nitidus* (21), *Geranium antrorsum* (21), *Agrostis venusta* (17), *Argyrotegium nitidulum* (8)

Other Common Taxa: *Poa costiniana* (40)

Significant Taxa: *Argyrotegium nitidulum, Euphrasia eichleri*

Weeds: *Acetosella vulgaris* (78), *Hypochaeris radicata* (34), *Cerastium glomeratum* (23), *Trifolium repens* (12), *Taraxacum officinale* (10), *Cerostium vulgare* (4), *Agrostis capillaris* (1)

Community 26: Bogong High Plains *Grevillea australis – Phebalium squamulosum* open heathland

Equivalent communities: Heathland/tussock grassland, Unit 3A & Grevillea scree heathland, Unit 3C (McDougall 1982).

This is the most common plant community on the Bogong High Plains, occurring on slopes, plains and some summits (e.g. Mt Bogong, Mt Hotham and Mt Feathertop) generally underlain by metamorphic or sedimentary material but extending into basaltic areas (Fig. 14). The community is dominated by *Grevillea australis* and / or *Phebalium squamulosum* subsp. *alpinum*, although low forms of *Orites lancifolia* are occasionally dominant in the northern part of its range (e.g. Mt Nelse). Grass cover (mostly *Poa hiemata* between shrubs and *P. hothamensis* under shrubs) is usually great and herb diversity is high. Community 26 intergrades with grassland (Community 25) on sites with deep soil profiles and with closed heathland (Community 47) on sites with shallow soil profiles. Cyclic processes of change between these communities probably occur (Williams 1992, McDougall 2003). Although some examples in ski resorts and along walking tracks will sustain damage from trampling or slashing, the community is widespread, well protected and under minimal threat. The significance of trampling will be greatest as the seedlings of *Grevillea australis*, an obligate seeder, attempt to re-establish after the 2003 fires.

No. quadrats 38; Native taxa / quadrat 23.4 ± 0.8; Total native taxa 100; Weeds /quadrat 1.5 ± 0.1; Total weed taxa 3

Altitude: 1560 – 1775 – 1960 m.

Diagnostic Taxa: Shrubs *Grevillea australis* (97), *Leucopogon* spp. (*hookeri, montanus*) (74), *Pimelea axiflora* subsp. *alpina* (53), *Asterolasia trymalioides* (50), *Olearia frostii* (50), *Phebalium squamulosum* subsp. *alpinum* (42), *Melicytus* sp. aff. *dentatus* (39), *Olearia brevipedunculata* (32), *Orites lancifolia* (24), *Exocarpos uamus* (13); **Herbs** *Carex breviculmis* (95), *Celmisia* spp. (89), *Craspedia* spp. (*coolaminica, jamesii*) (84), *Poa hothamensis* (82), *Oreomyrrhis eriopoda* (79), *Trisetum spicatum* (71), *Poa hiemata* (63), *Microseris* sp. 2 (55), *Scleranthus biflorus* (53), *Viola betonicifolia* (53), *Rytidosperma nudiflorum* (47), *Luzula modesta* (45), *Ranunculus victoriensis* (42), *Acaena novae–zelondiae* (39), *Brachyscome rigidula* (39), *Cardamine lilacina* (39), *Helichrysum rutidolepis* (37), *Brachyscome spathulato* (34), *Stellaria pungens* (34), *Scleranthus singuliflorus* (29), *Xerochrysum subundulatum* (26), *Euphrosia crassiuscula* (21), *Gonocarpus montanus* (21), *Goodenia hederocea* (18), *Ranunculus eichleriamus* (18)

Other Common Taxa: *Asperula gunnii* (71), *Leptorhynchos squamatus* subsp. *alpinus* (42)

Significant Taxa: *Euphrasia eichleri*

Weeds: *Acetosella vulgaris* (89), *Hypochaeris radicata* (47), *Cerastium glomeratum* (8)

Community 27: Bogong High Plains *Kunzea muelleri* open heathland

Equivalent communities: *Kunzea* heathland, Unit 4 (McDougall 1982).

This heathland is characterised by the dominance of *Kunzea muelleri*, a layering shrub usually less than 0.5 m tall in this community. It is found throughout the Bogong High Plains, often on sites with shallow soil. Species richness is generally lower than in other open heathlands of similar habitat. *Poa hiemata* is usually the dominant herb although its cover is variable, depending on the extent of *Kunzea muelleri*. In a grazing exclusion plot monitored over some decades (Wahren et al. 1994), *Kunzea* muelleri has spread into an area of Community 26 and become dominant. In the absence of disturbance it is possible that Community 27 expands into other communities. Although *Kunzea muelleri* was found to resprout following the 2003 fires, regeneration has been slow and many plants appear to have been killed. Periodic but rare fire probably limits the extent of this community. *Kunzea muelleri* stems are easily damaged by trampling and the paths of cattle and walkers are readily seen in many stands. Such damage is insubstantial because of the layering nature of the species. Protection from trampling damage will be important however while the species (and community) are recovering from the 2003 fires.

No. quadrats 29; Native taxa / quadrat 19.9 ± 0.6; Total native taxa 84; Weeds /quadrat 0.6 ± 0.1; Total weed taxa 4

Altitude: 1650 – 1790 – 1900 m.

Diagnostic taxa: Shrubs *Kunzea muelleri* (100), *Leucopogon* spp. (*hookeri, montanus*) (90), *Grevillea australis* (86), *Oreomyrrhis eriopoda* (62), *Pimelea alpina* (62), *Asterolasia trymalioides* (41), *Olearia frostii* (38), *Pimelea axiflora* subsp. *alpina* (24), *Podolobium alpestre* (21), *Ozothamnus alpinus* (17); **Herbs** *Asperula gunnii* (97), *Carex breviculmis* (93), *Celmisia* spp. (*costiniana, pugioniformis*) (90), *Craspedia* spp. (*coolaminica, jamesii*) (83), *Poa hiemata* (79), *Luzula modesta* (66), *Oreomyrrhis eriopoda* (62), *Brachyscome spathulata* (48), *Poa hothamensis* (48), *Senecio pinnatifolius* var. *alpinus* (45), *Erigeron nitidus* (41), *Brachyscome nivalis* (34), *Ranunculus victoriensis* (28), *Euphrasia crassiuscula* (17)

Other Common Taxa: *Leptorhynchos squamatus* subsp. *alpinus* (45)

Weeds: *Hypochaeris radicata* (28), *Acetosella vulgaris* (24), *Cerastium glomeratum* (3), *Taraxacum officinale* (3)

Community 28: Snowy Range open heathland

Equivalent communities: Alpine heathland, subcommunities 6.2 & 6.3 (Walsh et al. 1984).

Snowy Range open heathland is a grassy heathland community of sites of generally low relief, typically slopes falling gently to small watercourses. It occurs commonly on the Snowy Range between Mts Wellington and Howitt, but extends to the more isolated Mts Buller and Stirling areas. Soils may be basalt-derived, and, as in similar soils in the high country, of higher apparent fertility and water-holding capacity. Rock outcrops are common - the prostrate shrubs *Euryomyrtus ramosissima*, *Leucopogon fraseri* and *Pimelea alpina*

are often associated with shallow soils overlaying rock. These areas have a history of fairly intensive cattle grazing and the composition and structure may reflect this use (some examples have relatively high weed cover), but grazing has been withdrawn from most sites since 1992, and all sites since 2005. Although this is a locally common community with many examples in good condition, weed control in previously disturbed sites (e.g. old cattle holding yards and watering points) and sites currently used for horse yarding is necessary. Some seriously invasive species, e.g. *Juncus effusus* near watercourses or along tracks, now in manageable numbers, should be eliminated before they become ubiquitous through the range of the community.

No. quadrats 50; Native taxa / quadrat 23.4 ± 0.8; Total native taxa 142; Weeds /quadrat 2.2 ± 0.3; Total weed taxa 15

Altitude: 1340 – 1495 – 1680 m.

Diagnostic Taxa: Shrubs *Hovea montana* (92), *Leucopogon hookeri* (56), *Pimelea alpina* (46), *Euryomyrtus ramosissima* (34), *Bossiaea foliosa* (16), *Leucopogon fraseri* (16), *Bossiaea buxifolia* (4); **Herbs** *Carex breviculmis* (94), *Poa fawcettiae* (92), *Microseris* sp. 2 (84), *Leptorhynchos squamatus* subsp. *alpinus* (80), *Asperula gunnii* (78), *Craspedia* spp. (72), *Ranunculus graniticola* (68), *Viola betonicifolia* (66), *Schoenus apogon* (60), *Oreomyrrhis eriopoda* (54), *Trisetum spicatum* (52), *Celmisia* spp. (48), *Austrostipa nivicola* (40), *Rytidosperma nudiflorum* (40), *Stellaria pungens* (38), *Brachyscome scapigera* (36), *Erigeron bellidioides* (36), *Brachyscome spathulata* (30), *Lomandra orcophila* (28), *Euphrasia collina* subsp. *paludosa* (24), *Podolepis jaccoides* (18), *Agrostis hiemalis* sens. lat. (16), *Podolepis robusta* (16), *Luzula alpestris* (14), *Chiloglottis valida* (12), *Euchiton traversii* (10), *Austrodanthonia racemosa* (8), *Eriochilus cucullatus* (8)

Other Common Taxa: *Grevillea australis* (42)

Weeds: *Acetosella vulgaris* (58), *Hypochaeris radicata* (40), *Trifolium repens* (22), *Aphanes arvensis* (20), *Cerastium vulgare* (20), *Cerastium glomeratum* (16), *Aira caryophyllea* (6), *Leucanthemum vulgare* (6), *Poa pratensis* (6), *Holcus lanatus* (4), *Macrochia crecta* (4), *Taraxacum officinale* (4), *Vulpia bromoides* (4), *Trifolium dubium* (2), *Veronica arvensis* (2)

Community 29: Victorian shale *Hovea montana* heathland

Equivalent communities: Alpine heathland, subcommunity 6.1 (Walsh et al. 1984)

Confined to ridges and slopes of the upper catchments of the Macalister, Howqua, Delatite, Wonnangatta and King Rivers, this patchy open to closed heathland is structurally dominated by *Hovea montana*, *Leucopogon hookeri* and *Euryomyrtus ramosissima*, usually with *Poa fawcettiae* in gaps in the shrub canopy. It is established on relatively shallow soils derived from Palaeozoic mudstones and siltstones and usually occurs on moderately sloping sites of mainly northerly aspect. It is often contiguous with *Eucalyptus niphophila* woodlands and/or Community 48. Some sites supporting this community are traversed by the Alpine Walking Track and so receive localised damage, but generally the community is not particularly prone to disturbance. Even before the cessation of grazing across all examples of the community, it was not favoured by stock due to the relatively low proportion of palatable species

No. quadrats 37; Native taxa / quadrat 20.2 ± 0.8; Total native taxa 128; Weeds /quadrat 1.3 ± 0.1; Total weed taxa 5

Altitude: 1460 – 1610 – 1740 m.

Diagnostic Taxa: Shrubs *Hovea montana* (68), *Leucopogon hookeri* (65), *Euryomyrtus ramosissima* (43), *Podolobium alpestre* (35); **Herbs** *Poa fawcettiae* (89), *Carex breviculmis* (86), *Microseris* sp. 2 (78), *Celmisia* spp. (65), *Stellaria pungens* (65), *Brachyscome spathulata* (54), *Trisetum spicatum* (51), *Leptorhynchos squamatus* subsp. *alpinus* (49), *Arthropodium milleflorum* (46), *Stylidium* spp. (46), *Luzula novae–cambriae* (43), *Prasophyllum* spp. (41), *Bulbine bulbosa* (35), *Goodenia hederacea* subsp. *alpestris* (35), *Chrysocephalum semipapposum* (32), *Euphrasia collina* subsp. *paludosa* (32), *Aciphylla glacialis* (30), *Agrostis venusta* (27), *Leucochrysum albicans* subsp. *alpinum* (27), *Brachyscome rigidula* (22), *Rhodanthe anthemoides* (22), *Austrodanthonia eriantha* (16), *Elymus scaber* (16), *Lomandra oreophila* (16), *Galium gaudichaudii* (11)

Other Common Taxa: *Craspedia* spp. (65), *Asperula gunnii* (62)

Weeds: *Hypochaeris radicata* (57), *Acetosella vulgaris* (54), *Aira caryophyllea* (8), *Cerastium glomeratum* (5), *Leucanthemum vulgare* (3)

Group VIII – subalpine grasslands & open heathlands

Community 30: *Poa hiemata – Poa clivicola* grassland

Equivalent communities: Vegetation Type 2 (Helman & Gilmour 1985); Group 16 (Helman et al. 1988); Community 6 (Benson 1994).

This is the most common grassland of the treeless plains in Kosciuszko National Park, occurring from the upper Thredbo Valley in the south to Emu Plain in the west, Cooleman Plain in the north and Snowy Plain in the east (Fig. 7). It also occurs in the ACT at Cheyenne Flat and Bimberi (and probably elsewhere). The community is the dominant of large plains such as Kiandra, Happy Jacks and Long Plains. It is characterised by a dense cover of one, or often several species of *Poa* (mainly *P. clivicola*, *P. costiniana* or *P. hiemata* but occasionally *P. petrophila* or *P. phillipsiana*) with numerous intertussock spaces containing a large range of herbaceous species. Tall shrubs such as *Hakea microcarpa* and *Cassinia monticola* may be present and at times are abundant enough for the vegetation to be effectively an open heathland. Despite the greater shrub cover, such examples are floristically indistinct from surrounding grasslands. This community has the highest mean native species richness/ quadrat of the grasslands identified. Examples in the Snowy Plain area are on freehold land and grazed by cattle. Pigs are a significant threat to the community in some places (e.g. Nungar and Happy Jacks Plains). Patches of up to 100 m^2 may be overturned by pigs causing the exposure of bare soil, a large reduction in the cover of *Poa* species, and an increase in disturbance tolerant species such as *Geranium antrorsum*, *Drabastrum alpestre* and *Stellaria multiflora* (McDougall and Walsh 2002).

No. quadrats 50; Native taxa / quadrat 29.9 ± 0.8; Total native taxa 183; Weeds /quadrat 2.1 ± 0.3; Total weed taxa 16

Altitude: 1250 – 1475 – 1810 m.

Diagnostic Taxa: Shrubs *Leucopogon hookeri* (58), *Pimelea linifolia* subsp. *cacsia* (46), *Cassinia monticola* (38), *Pimelea biflara* (26), *Oxylobium ellipticum* (18), *Hovea* aff. *heterophylla* (8), *Pultenaea fasciculata* (8), *Pultenaea polifolia* (8); **Herbs** *Ranunculus graniticola* (94), *Carex breviculmis* (92), *Craspedia* spp. (*coolaminica*, *crocata*, *jamesii*) (76), *Schoenus biflorus* (74), *Leptorhynchos squamatus* subsp. *alpinus* (72), *Geranium antrorsum* (68), *Microseris* sp. 2 (60), *Poranthera microphylla* (58), *Aciphylla simplicifolia* (56), *Poa hiemata* (56), *Senecio pinnatifolius* var. *alpinus* (50), *Oreomyrrhis argentea* (48), *Luzula flaccida* (46), *Xerochrysum subundulatum* (44), *Stylidium montanum* (40), *Trisetum spicatum* (40), *Prasophyllum sphacelatum* (38), *Brachyscome decipiens* (38), *Euphrasia collina* subsp. *paludosa* (38), *Poa clivicola* (36), *Australopyrum velutinum* (34), *Erigeron bellidioides* (34), *Cardamine lilacina* (30), *Epilobium billardierianum* (30), *Ajuga australis* (28), *Brachyscome scapigera* (28), *Acaena echinata* (26), *Brachyscome aculeata* (22), *Poa phillipsiana* (22),

Rhytidasparum alpinum (22), *Scleranthus fascicularis* (22), *Asperula scoparia* (20), *Diuris monticola* (20), *Podolepis jaceoides* (20), *Rhodanthe anthemoides* (20), *Arthropodium milleflorum* (18), *Festuca asperula* (16), *Plantago antarctica* (16), *Stellaria multiflora* (16), *Linum marginale* (14), *Lobelia pedunculata* (12), *Leptorhynchos elongatus* (10), *Picris angustifolia* subsp. *merxmuelleri* (10), *Senecio* spp. *(lageniformis, longipilus)* (10), *Paa petrophila* (8), *Taraxacum aristum* (6)

Other Common Taxa: *Asperula gunnii* (70), *Poa costiniana* (48), *Celmisia pugioniformis* (46),

Significant Taxa: *Calotis glandulasa, Diuris pedunculata, Galium roddii* (rarely, on rocky outcrops within grassland), *Prasophyllum retroflexum, Rutidosis leialepis*

Weeds: *Acetosella vulgaris* (72), *Hypochaeris radicata* (38), *Trifolium repens* (26), *Cerastium vulgare* (18), *Taraxacum officinale* (12), *Anthoxanthum odoratum* (8), *Cerastium glameratum* (6), *Crepis capillaris* (6), *Cirsium vulgare* (4), *Tragopogon dubius* (4), *Aira elegans* (2), *Holcus lanatus* (2), *Trifolium arvense* (2), *Trifalium campestre* (2), *Viala tricolor* (2), *Vulpia bromaides* (2)

Community 31: Poa hookeri grassland

Equivalent communities: Nil

Patches of this grassland community are often found within larger stands of Community 30. The two communities are easily distinguished however. Community 31 is dominated by *Poa haokeri*, a much shorter tussock species than those dominant in Community 30. Many prostrate and mat-forming species are present (e.g. *Calatis pubescens, Caprosma nivalis, Dillwynia prostrata, Pimelea biflora, Pultenaea fasciculata, Pultenaea palifolia, Rutidasis leiolepis*). The herbaceous flora between the sparse, short tussocks is diverse. Most examples of this community occur between Long Plain and Nungar Plain in Kosciuszko National Park, with an outlier between Snowy and Botherum Plain. The community is geographically restricted and most patches are small. Pigs are a major threat in the Nungar area. Some examples in the Snowy Plain area are on freehold land and grazed by cattle. Rabbits are also common there and in the adjoining National Park. Pigs seem to overturn plants preferentially in this type of grassland.

No. quadrats 22; Native taxa / quadrat 27.4 ± 1.4; Total native taxa 117; Weeds /quadrat 2.4 ± 0.3; Total weed taxa 15

Altitude: 1200 – 1320 – 1420 m.

Diagnostic Taxa: Shrubs *Leucapogon hookeri* (59), *Pimelea linifolia* subsp. *caesia* (59), *Hovea* aff. *heteraphylla* (32), *Pultenaea palifolia* (32), *Pimelea biflara* (23), *Pultenaea fasciculata* (23), *Dillwynia prostrata* (18), *Coprosma nivalis* (14); **Herbs** *Carex breviculmis* (100), *Paa hookeri* (100), *Geranium antrorsum* (91), *Craspedia* spp. (*coolaminica, jamesii*) (86), *Ranunculus graniticola* (82), *Scleranthus biflarus* (82), *Podolepis jaceoides* (73), *Austrodanthonia* spp. (*eriantha, laevis*) (64), *Luzula flaccida* (64), *Microseris* sp. 2 (59), *Rhodanthe anthemaides* (55), *Senecio pinnatifalius* var. *alpinus* (55), *Poa plullipsiana* (50), *Trisetum spicatum* (50), *Brachyscame aculeata* (45), *Plantago euryphylla* (45), *Epilabium billardierianum* (41), *Oreonnyrrhis argentea* (41), *Poa clivicola* (41), *Acaena echinata* (36), *Ajuga australis* (36), *Euphrasia callina* subsp. *paludosa* (36), *Paranthera micraphylla* (32), *Rutidosis leialepis* (32), *Diuris monticala* (27), *Poa petrophila* (27), *Drabastrum alpestre* (23), *Euchiton collinus* (23), *Leptarhynchos elongatus* (18), *Senecio longipilus* (18), *Themeda triandra* (18), *Carex incanitata* (14), *Bulbine* aff. *glauca* (9), *Calotis glandulasa* (9)

Other Common Taxa: *Asperula gunnii* (59)

Significant Taxa: *Bulbine* aff. *glauca, Calotis glandulosa, Calotis pubescens, Rutidosis leiolepis, Wahlenbergia densifolia*

Weeds: *Hypochaeris radicata* (82), *Acetosella vulgaris* (59), *Cerastium vulgare* (23), *Trifolium repens* (23), *Aira caryophyllea* (9), *Anthoxanthum odoratum* (9), *Crepis capillaris* (9), *Vulpia bromaides* (9), *Cerastium glameratum* (5), *Dianthus armeria* (5), *Hypericum perforatum* (5), *Myasotis discolor* (5), *Paa pratensis* (5), *Taraxacum officinale* (5), *Tragopogon dubius* (5)

Community 32: Hovea montana – Poa phillipsiana open heathland

Equivalent communities: Alpine heathland, subcommunity 6.4 (Walsh et al. 1984).

This is the commonest grassland/open heathland community on Mt Buffalo where it occurs in broad valleys below the inverted treeline (Fig. 15). It occupies similar topological sites on other mountains (e.g. Davies Plain, Cobberas) and has not yet been recorded above the upper treeline. Soils typically contain less organic matter than other grasslands and are often shallow and/or gravelly. *Poa phillipsiana* generally provides most of the vegetated cover but the robust tussock *Austrostipa nivicola* may be co-dominant. Shrubs such as *Hovea montana* and *Grevillea australis* are often present and suggest an ecotonal position in some sites. A range of robust, conspicuous daisies (e.g. *Craspedia* spp., *Brachyscome spathulata, Podolepis rabusta, Xerochrysum subundulatum*) make this a visually striking community in peak flowering period. All representatives of this community on Mt Buffalo are well protected and have regenerated well after the 2003 fires, retrieving most, if not all, their pre-fire diversity. Examples on the Nunniong Plateau and the Cobberas mountains are subject to grazing and trampling by cattle and/or feral horses. This has resulted in entrenched paths and extensive latrine areas which are nursery sites for weeds.

No. quadrats 24; Native taxa / quadrat 21.0 ± 0.9; Total native taxa 108; Weeds /quadrat 1.2 ± 0.2; Total weed taxa 4

Altitude: 1160 – 1470 – 1700 m.

Diagnostic Taxa: Shrubs *Hovea montana* (83); **Herbs** *Poa phillipsiana* (100), *Craspedia* spp. (96), *Carex breviculmis* (92), *Scleranthus biflarus* (83), *Austradanthonia pilosa* (79), *Leptorhynchos squamatus* subsp. *alpinus* (79), *Brachyscone spathulata* (67), *Ranunculus graniticola* (63), *Ajuga australis* (58), *Austrostipa nivicola* (50), *Luzula modesta* (50), *Erigeron bellidioides* (42), *Podalepis robusta* (38), *Xerochrysum subundulatum* (38), *Australopyron velutinum* (25), *Lobelia pedunculata* (17)

Other Common Taxa: *Asperula gunnii* (46), *Microseris* sp. 2 (46), *Pimelea alpina* (42)

Weeds: *Acetosella vulgaris* (58), *Hypachaeris radicata* (33), *Cerastium glomeratum* (21), *Trifolium repens* (13)

Community 33: Northern Alps *Hovea montana* open heathland

Equivalent communities: not clearly identified in previous vegetation descriptions.

Havea montana (to a height of about 0.5 m) is the usual dominant of this community in an open community interspersed with patches of tussock grasses (commonly *Poa clivicola, P. fawcettiae* or *P. phillipsiana*). One of several shrubs (e.g. *Cassinia manticola, Grevillea australis, Podolobium alpestre*) may occasionally dominate and *Austrostipa nivicola* is abundant at several sites. Community 33 commonly occupies sites with greater soil depth than Community 37 and may occur in mosaic with Community 30. It is found in Kosciuszko National Park (Kiaudra, Happy Jacks Plain, Tautangara area) and Namadgi National Park (Mt Bimberi, Mt Murray, Mt Gingera). This community is well protected and not under any obvious threat at present.



Fig. 13. Community 25 covers most of the floor of Pretty Valley on the Bogong High Plains (in a mosaic with *Epacris* moist heathland (Community 4), which is found in moist areas). Large sections of the community here are dominated by *Pentachondra pumila*, a mat-forming shrub. In such cases, tussock grasses may be uncommon but diversity high.



Fig. 14. Open heathland dominated by *Grevillea australis* and *Phebalium squamulosum* var. *alpinum* with large, herb-rich gaps (Community 26), is the most common community on the Bogong High Plains. *Asterolasia tryonioides* (seen here in flower) is occasionally abundant.

No. quadrats 8; Native taxa / quadrat 24.0 ± 0.9; Total native taxa 94; Weeds /quadrat 1.3 ± 0.4; Total weed taxa 4

Altitude: 1330 – 1505 – 1800 m.

Diagnostic Taxa: Shrubs *Hovea montana* (100), *Leucopogon hookeri* (75), *Pimelea linifolia* subsp. *caesia* (63), *Grevillea australis* (50), *Pimelea biflora* (50), *Cassinia monticola* (38); **Herbs** *Carex breviculmis* (100), *Microseris* sp. 2 (100), *Craspedia* spp. (*coolaminica, jamesii*) (88), *Celmisia* spp. (*pugioniformis*) (75), *Ranunculus graniticola* (75), *Aciphylla simplicifolia* (63), *Austrostipa nivicola* (63), *Linum marginale* (50), *Oreomyrrhis argentea* (50), *Poa phillipsiana* (50), *Helichrysum rutidolepis* (38), *Rhodanthe anthemoides* (38)

Other Common Taxa: *Asperula gunnii* (63), *Leptorhynchos squamatus* subsp. *alpinus* (50), *Scleranthus biflorus* (50), *Stellaria pungens* (50), *Stylidium montanum* (50)

Weeds: *Acetosella vulgaris* (50), *Anthoxanthum odaratum* (13), *Hypochaeris radicata* (13), *Vulpia bromoides* (13)

Community 34: *Eucalyptus lacrimans* low open woodland

Equivalent communities: Nil

This open woodland community occurs on isolated knolls and low ridges of frost hollows between Long and Nungar Plains in Kosciuszko National Park (including the Kiandra area and Currango Plain). *Eucalyptus lacrimans* is the structural dominant but it is invariably very sparse. The understorey ranges from grass-dominated (most commonly *Poa phillipsiana*) to shrub-dominated (mostly *Hakea microcarpa*) (Fig. 16). Several species that are uncommon on the treeless plains were recorded in this community (*Daviesia ulicifolia, Dichelachne rara, Grevillea lanigera, Lepidosperma curtisiae, Lomandra longifolia* var. *exilis, Phebalium squamulosum* subsp. *ozothamnoides, Tetratheca bauerifolia*). Woodland dominated by *Eucalyptus lacrimans* occurs in Kosciuszko National Park and the Adaminaby area to the east. The Kosciuszko National Park community appears to be distinct from the Adaminaby community, the understorey of which is dominated by *Themeda triandra* and contains many elements of the Monaro Plains flora. Community 34 is highly localised. Most examples contain dead trees of *Eucalyptus lacrimans* and little or no recruitment of this species. The reason for the possible decline of the dominant species in this community warrants investigation. Some examples of this woodland were burnt in the 2003 fires. Recruitment and survival of *Eucalyptus lacrimans* should be monitored in burnt and unburnt examples to determine if fire plays a role in regeneration.

No. quadrats 5; Native taxa / quadrat 26.2 ± 0.9; Total native taxa 69; Weeds /quadrat 2.2 ± 0.7; Total weed taxa 5

Altitude: 1270 – 1340 – 1470 m.

Diagnostic Taxa: Shrubs *Eucalyptus lacrimans* (100), *Hakea microcarpa* (100), *Pimelea linifolia* subsp. *caesia* (100), *Leucopogon hookeri* (80), *Dillwynia prostrata* (40), *Hovea* aff. *heterophylla* (40), *Olearia myrsinoides* (40); **Herbs** *Carex breviculmis* (100), *Craspedia* spp. (*caolaminica, jamesii*) (100), *Poranthera microphylla* (100), *Trisetum spicatum* (100), *Austrodanthonia laevis* (80), *Poa phillipsiana* (80), *Elymus scaber* (60), *Linum marginale* (40), *Themeda triandra* (40)

Other Common Taxa: *Microseris* sp. 2 (80), *Scleranthus biflorus* (80); *Asperula gunnii* (60), *Ranunculus graniticola* (60)

Weeds: *Hypochaeris radicata* (80), *Acetosella vulgaris* (60), *Cerastium vulgare* (40), *Crepis capillaris* (20), *Tragopogon dubius* (20)

Community 35: *Bossiaea foliosa – Epacris petrophila* heathland

Equivalent communities: Nil

This open to closed heathland is apparently restricted to the Long Plain – Bullocks Hill area of Kosciuszko National Park where locally abundant. The community is characterised by a moderate to dense cover of *Bossiaea foliosa* and / or *Epacris petraphila*. The ground layer is usually sparse and of low diversity, *Poa phillipsiana* and *Poa clivicola* made up most of the ground cover in the examples sampled. In places, especially where dominated by *Bossiaea foliasa*, this community is continuous with understorey vegetation of adjoining snow gum woodland, and is perhaps more characteristic of woodland vegetation than of the vegetation of the plains. Although similar in appearance, the extensive stands of this community dominated by *Epacris petrophila* in Long Plain are floristically distinct from stands dominated by this shrub in the Kiandra valley nearby, which are part of Community 37. Community 35 is abundant where it occurs and appears to be encroaching on grassland vegetation based on a cursory examination of 1970 aerial photography. It is well protected and under little threat at present.

No. quadrats 4; Native taxa / quadrat 17.8 ± 2.8; Total native taxa 43; Weeds /quadrat 1.5 ± 0.5; Total weed taxa 4

Altitude: 1320 – 1340 – 1360 m.

Diagnostic Taxa: Shrubs *Bossiaea foliosa* (75), *Epacris petrophila* (75), *Pimelea linifolia* subsp. *caesia* (75); **Herbs** *Carex breviculmis* (100), *Xerochrysum subundulatum* (100), *Acaena echinata* (75), *Geranium antrorsum* (75), *Poa phillipsiana* (75), *Poa petrophila* (50)

Other Common Taxa: *Celmisia pugioniformis* (50), *Craspedia* spp. (*coolaminica, jamesii*) (75), *Austrodanthonia* spp. (50), *Leptorhynchos squamatus* subsp. *alpinus* (50), *Poa clivicola* (50), *Poranthera microphylla* (50), *Ranunculus graniticola* (50), *Stellaria pungens* (50), *Stylidium montanum* (50)

Weeds: *Acetosella vulgaris* (75), *Cerastium vulgare* (25), *Taraxacum officinale* (25), *Trifolium repens* (25)

Community 36: Broadway *Bossiaea foliosa* closed heathland

Equivalent communities: Nil

This heathland appears to be restricted to the slopes and ridges of the upper Tooma River valley (Toolong, Broadway and Pretty Plains). It is characterised by a dense cover of *Bossiaea foliosa* (to about 1.25 m tall) and, unlike other closed heathlands in the Australian Alps, a very diverse understorey. The mean species richness of this community was the highest recorded. The understorey is dominated by forbs and, although *Paa phillipsiana* was commonly recorded, tussock grasses are not abundant. Almost all of this community was burnt in January 2003. Although not recorded in the quadrats before the fire, *Dichelachne crinita* was common and prominent 12 months after. Community 36 is geographically restricted but the most common community within its range. It has closer affinities with open heath and grassland communities, where *Bossiaea foliosa* is rare or absent than with closed shrub communities where it is abundant. It is possible that this community is an artefact of past grazing management, either through overgrazing (which creates bare spaces that are favourable to shrub germination) or through the frequent burning of grassland to promote new, more palatable growth of grass (which also creates bare ground and would stimulate germination of leguminous seed such as that of *Bossiaea faliosa*). The entire community is well protected across its range. It will be vulnerable to disturbance (from vehicles and feral animals) while it is recovering from the fire.

No. quadrats 5; Native taxa / quadrat 36.6 ± 3.2; Total native taxa 85; Weeds /quadrat 1.8 ± 0.5; Total weed taxa 3

Altitude: 1250 – 1285 – 1350 m.

Diagnostic Taxa: Shrubs *Bossiaea foliosa* (100), *Cassinia monticola* (100), *Hakea microcarpa* (100), *Leucopogon hookeri* (100), *Pimelea*

linifolia subsp. *caesia* (80), *Kunzea muelleri* (60), *Ozothamnus secundiflorus* (40); **Herbs** *Carex breviculmis* (100), *Craspedia* spp. (*coolaminica, jamesii*) (100), *Viola betonicifolia* (100), *Brachyscome aculeata* (80), *Geranium antrorsum* (80), *Leptorhynchos squamatus* subsp. *alpinus* (80), *Poranthera microphylla* (80), *Ranunculus graniticola* (80), *Erigeron bellidioides* (60), *Goodenia hederacea* subsp. *alpestris* (60), *Oreomyrrhis argentea* (60), *Poa phillipsiana* (60), *Podolepis hieracioides* (60), *Senecio gunnii* (60), *Xerochrysum subundulatum* (60), *Austrodanthonia oreophila* (40), *Dichelachne crinita* (40), *Linum marginale* (40), *Lobelia pedunculata* (40)

Other Common Taxa: *Asperula gunnii* (80), *Ajuga australis* (60), *Celmisia pugioniformis* (60), *Grevillea australis* (60), *Hovea montana* (60), *Stellaria pungens* (60), *Stylidium* spp. (*montanum*) (60), *Trisetum spicatum* (60)

Weeds: *Acetosella vulgaris* (100), *Cerastium vulgare* (40), *Hypochaeris radicata* (40)

Community 37: Northern Alps *Epacris – Kunzea* open heathland

Equivalent communities: Nil

Although *Kunzea muelleri* was present in almost all quadrats sampled in this community and is often the dominant shrub, in many examples it is inconspicuous and the community is then dominated by *Epacris petrophila* (especially in the Kiandra area) or *E. gunnii*. Community 37 appears to be confined to the subalpine plains of Kosciuszko National Park (e.g. Happy Jacks Plain, Toolong Plain, Munyang Creek, Kiandra). Soils are sometimes, but not invariably, shallow. Species richness is high. *Poa clivicola* (and sometimes other *Poa* species) provide most of the ground cover but various inter-tussock species are common. This community appears to be well protected and under little threat at present. Regeneration of the dominants in examples burnt in 2003 has been slow and large areas were still bare two years after the fire. It will be important to minimise disturbance in these areas to facilitate recovery.

No. quadrats 14; Native taxa / quadrat 25.9 ± 1.4; Total native taxa 90; Weeds /quadrat 0.7 ± 0.1; Total weed taxa 4

Altitude: 1250 – 1465 – 1620 m.

Diagnostic Taxa: Shrubs *Kunzea muelleri* (93), *Epacris gunnii* (50), *Pimelea biflora* (50), *Epacris petrophila* (43), *Pultenaea fasciculata* (21); **Herbs** *Carex breviculmis* (100), *Craspedia* spp. (*coolaminica, crocata, jamesii*) (93), *Poranthera microphylla* (86), *Poa clivicola* (79), *Ranunculus graniticola* (79), *Scleranthus biflorus* (79), *Aciphylla simplicifolia* (71), *Geranium antrorsum* (64), *Leptorhynchos squamatus* subsp. *alpinus* (64), *Senecio pinnatifolius* var. *alpinus* (64), *Cardamine lilacina* (57), *Austrodanthonia* spp. (*laevis*) (50), *Erigeron bellidioides* (50), *Oreomyrrhis argentea* (50), *Brachyscome scapigera* (43), *Luzula flaccida* (43), *Xerochrysum subundulatum* (43), *Euphrasia collina* subsp. *paludosa* (36), *Rhytidosporum alpinum* (21)

Other Common Taxa: *Asperula gunnii* (71), *Celmisia pugioniformis* (50), *Brachyscome decipiens* (43), *Brachyscome spathulata* (43), *Grevillea australis* (43), *Microseris* sp. 2 (43)

Weeds: *Acetosella vulgaris* (43), *Cerastium vulgare* (14), *Cirsium vulgare* (7), *Hypochaeris radicata* (7)

Group IX – limestone grassland

Community 38: *Themeda triandra – Leucochrysum albicans* grassland

Equivalent communities: Nil

This grassland community is common on steep slopes in the Blue Waterholes area of Kosciuszko National Park, where it occurs on loose limestone scree and around rocky outcrops. *Themeda triandra* is dominant in most areas, although plant cover is sometimes sparse. There are occasional emergent shrubs of *Cassinia ochracea*, *Grevillea lanigera* and *Hakea microcarpa* but shrub cover is generally low. Slopes in similar habitat at Yarrangobilly Caves about 25 km south of Blue Waterholes support small pockets of this community within a forested landscape. The Cave Creek area has a high diversity of weeds, some of which are locally abundant. *Sedum acre* occupies a niche on rocky sites also occupied by the very restricted *Galium roddii*, which appears to be threatened as a result. Many of the weeds present in Cave Creek are locally dominant in similar habitat at Yarrangobilly Caves (e.g. *Potentilla recta, Rosa rubiginosa, Tragopogon dubius, Verbascum thapsus*). Control of these and other weed species may be required in the future. Control will be difficult however because the steep slopes of Cave Creek are unstable and frequent pedestrian traffic could have a significant impact on plants growing there.

No. quadrats 6; Native taxa / quadrat 16.2 ± 1.5; Total native taxa 32; Weeds /quadrat 6.2 ± 1.2; Total weed taxa 15

Altitude: 1200 – 1220 m.

Diagnostic Taxa: Shrubs *Cassinia ochracea* (83), *Grevillea lanigera* (33), *Hakea microcarpa* (83), *Pimelea linifolia* subsp. *caesia* (83), *Muehlenbeckia axillaris* (33); **Herbs** *Carex breviculmis* (100), *Leucochrysum albicans* subsp. *alpinum* (100), *Poa fawcettiae* (100), *Themeda triandra* (100), *Picris angustifolia* subsp. *merxmuelleri* (83), *Xerochrysum* aff. *viscosum* (83), *Convolvulus angustissimus* subsp. *angustissimus* (67), *Galium roddii* (67), *Linum marginale* (67), *Vittadinia cuneata* (67), *Craspedia coolaminica* (50), *Plantago varia* (50), *Clematis microphylla* var. *leptophylla* (33), *Derwentia perfoliata* (33)

Significant Taxa: *Galium roddii, Thesium australe*

Weeds: *Trifolium dubium* (83), *Hypochaeris radicata* (67), *Rosa rubiginosa* (67), *Sedum acre* (67), *Tragopogon dubius* (67), *Cerastium vulgare* (50), *Crepis capillaris* (50), *Echium vulgare* (33), *Linaria arvensis* (33), *Petrorhagia nanteuilii* (33), *Cerastium glomeratum* (17), *Taraxacum officinale* (17), *Verbascum thapsus* (17), *Verbascum virgatum* (17), *Vulpia bromoides* (17)

Group X – Short alpine heathlands

Community 39: Kosciuszko alpine *Epacris – Kunzea* open heathland

Equivalent communities: *Epacris serpyllifolia – Kunzea muelleri* alliance (Costin 1954); a combination of the *Epacris microphylla* and *Kunzea muelleri* associations (McVean 1969).

Community 39 is a low heathland dominated by *Epacris gunnii*, *Kunzea muelleri* or occasionally *E. petrophila*, occurring on the upper granite or phyllite slopes and summits of the Kosciuszko Main Range. Sites containing this community are generally rocky with shallow soil. Community 39 has some floristic elements of Community 40 (*Epacris gunnii – Chionohebe pulvinatus* feldmark; e.g. *Leucochrysum albicans* and *Luzula australasica*) but the cushion species are absent. An unusual feature of some Community 39 stands is the presence of *Baeckea gunniana*, a species usually associated with moist sites. It can sometimes be found layering over large granite boulders. The diversity and abundance of herb species is usually low. Rock and bare ground are common. On less exposed sites with deeper soil profiles, Community 39 may grade into Community 23. Some examples (e.g. summit of Mt Kosciuszko) are subject to trampling pressure by tourists. The top stations of some lifts in NSW ski resorts are positioned within this community. The impact of these pressures on the overall community is currently low.

No. quadrats 17; Native taxa / quadrat 15.2 ± 1.0; Total native taxa 69; Weeds /quadrat 0.4 ± 0.0; Total weed taxa 1

Altitude: 1860 – 2005 – 2220 m.

Diagnostic Taxa: Shrubs *Epaeris gunnii* (65), *Epacris petrophila* (35), *Kunzea muelleri* (35), *Oxylobium ellipticum* (24); **Herbs** *Celmisia* spp. (*eostiniana, pugioniformis*) (88), *Poa fawcettiae* (71), *Ewartia nubigena* (53), *Leucochrysum albicans* subsp. *alpinum* (53), *Lycopodium fastigiatum* (35), *Scleranthus singuliflorus* (29), *Deyeuxia crassiuscula* (24), *Deyeuxia monticola* (24), *Luzula alpestris* (24), *Luzula australasica* subsp. *dura* (24), *Oreomyrrhis brevipes* (24), *Poa saxicola* (18)

Other Common Taxa: *Craspedia* spp. (*aurantia, maxgrayi*) (76), *Carex breviculmis* (53), *Grevillea australis* (47)

Weeds: *Acetosella vulgaris* (35)

Community 40: *Epacris gunnii – Chionohebe pulvinatus* feldmark

Equivalent communities: *Epaeris petrophila – Veronica densifolia* alliance (Costin 1954); *Epacris microphylla – Veronica densifolia* association (McVean 1969); *Epacris – Chionohebe* Feldmark (Costin et al. 2000).

This dwarf heathland, referred to as feldmark by Costin et al. (2000), occurs on the Kosciuszko Main Range between Mt Twynam and Rawsons Pass, most commonly on exposed ridgetops and summits. Total plant cover is normally less than 50%, pavements of fractured sedimentary rock being a feature of the habitat. *Epaeris gunnii* is the usual dominant. These shrubs are pruned by prevailing winds on the western side but continue to grow on the sheltered eastern side, thus moving slowly across the community (Barrow et al. 1968) (Fig. 17). Some examples, especially in the Mt Twynam area, contain little or no *Epacris gunnii*. Throughout its distribution, the community is characterised by the presence, often in low numbers, of cushion plants and prostrate herbs, some largely restricted to this community (e.g. *Colobanthus pulvinatus, Ranunculus acrophilus, Rytidosperma pumilum, Chionohebe densifolia, Euphrasia collina* subsp. *lapidosa, Kelleria dieffenbaehii*). Community 40 may apparently develop on protected slopes and ridges of similar geology when plant and soil cover are lost from other communities (Costin et al. 2000). The walking track along the Main Range passes through several examples. Whilst plant death has occurred on the track surface, the overall effect appears to have been localised. Such walking tracks have created a barrier to the movement of *Epacris gunnii* from windward to leeward (McDougall & Wright 2004) but the impact is barely noticeable. The Main Range Track should ultimately be moved to avoid feldmark communities.

No. quadrats 6; Native taxa / quadrat 14.8 ± 2.2; Total native taxa 36; Weeds /quadrat 0.5 ± 0.3; Total weed taxa 2

Altitude: 2010 – 2100 – 2150 m.

Diagnostic Taxa: Shrubs *Epaeris gunnii* (67); **Herbs** *Colobanthus pulvinatus* (100), *Ewartia nubigena* (100), *Luzula australasica* subsp. *dura* (100), *Poa fawcettiae* (100), *Ranunculus acrophilus* (83), *Trisetum spicatum* (83), *Agrostis muelleriana* (67), *Chionohebe densifolia* (67), *Euphrasia collina* subsp. *lapidosa* (67), *Leucochrysum albicans* subsp. *alpinum* (67), *Senecio pectinatus* var. *major* (67), *Kelleria dieffenbachii* (33), *Rytidosperma pumilum* (33)

Other Common Taxa: *Celmisia* spp. (*costiniana, pugioniformis*) (50)

Significant Taxa: *Euphrasia* sp. 3 (Ramshead Range), *Rytidosperma pumilum*

Weeds: *Acetosella vulgaris* (33), *Hypochaeris radicata* (17)

Community 41: Bogong High Plains *Epacris – Kunzea* open heathland

Equivalent communities: *Epacris microphylla* heathland, Unit 14 (McDougall 1982).

This low heathland, which is dominated by *Epacris gunnii*, is structurally and floristically similar to Community 40 of the Kosciuszko Main Range. It is most commonly found on high summits of the Bogong High Plains (e.g. Mt Nelse) but may also occur at lower elevations on sites with skeletal soil. On such sites, *Kunzea muelleri* may be co-dominant. On high altitude exposed sites, there is evidence of the lateral movement of *Epaeris gunnii* shrubs across the community, with stems being pruned on the windward side and growing out on the leeward (as in Community 40). Floristic diversity is low and rock cover great. Tussock grasses, although frequent, provide little cover. Because of their occurrence on summits that are popular with tourists, some trampling damage does occur. This has had minimal effect in the past but may be more significant in the coming years as most examples were burnt in 2003. *Epacris gunnii* is an obligate seeder and will take many years to return to its pre-fire abundance in the harsh, exposed habitat of this community.

No. quadrats 8; Native taxa / quadrat 14.3 ± 0.9; Total native taxa 29; Weeds /quadrat 0.1; Total weed taxa 1

Altitude: 1630 – 1825 – 1880 m.

Diagnostic Taxa: Shrubs *Epacris gunnii* (100), *Grevillea australis* (75), *Kunzea muelleri* (75), *Leucopogon* spp. (*hookeri, montanus*) (63); **Herbs** *Carex breviculmis* (100), *Ewartia nubigena* (100), *Poa fawcettiae* (88), *Poa hiemata* (88), *Deyeuxia monticola* (75), *Luzula novae-cambriae* (63), *Agrostis parviflora* (38), *Leucochrysum albicans* subsp. *alpinum* (38)

Other Common Taxa: *Asperula gunnii* (63), *Celmisia* spp. (*costiniana, pugioniformis*) (63), *Luzula modesta* (63), *Oreomyrrhis eriopoda* (63),

Significant Taxa: *Euphrasia crassiuscula* subsp. *glandulifera, Euphrasia eichleri*

Weeds: *Taraxacum officinale* (13)

Group XI – western subalpine open heathland

Community 42: *Epacris celata – Poa clivicola* open heathland

Equivalent communities: Nil

This community is currently recorded only from McPhersons Plain, part of a high plateau on the western side of the Tumut Valley, to the west of Kosciuszko National Park. Other treeless plains on the plateau nearby (Sparks Plain and Tomneys Plain) have not been surveyed so it is possible that it is not restricted to McPhersons Plain. The community comprises very short plants of *Epaeris celata* and *E. gunnii*. In stature and abundance, the shrubs are less prominent than the grasses (*Poa clivicola, Poa sieberiana* and *Themeda triandra*), which makes the community look more like a grassland than an open heathland. Community 42 is not closely related to any of the other communities described in this paper. This community appears to be rare and isolated from other treeless vegetation in the Australian Alps. It is not present in a conservation reserve. McPhersons Plain is partly in a State Forest lease and partly freehold. Other plains in the vicinity that might contain the community are freehold land. Some of the community is the subject of a conservation agreement that fosters management of the vegetation for its significant features. Despite this, the community is threatened overall by feral animals, stray domestic stock from neighbouring properties, and future changes in land use.

No. quadrats 3; Native taxa / quadrat 26.0 ± 2.1; Total native taxa 46; Weeds /quadrat 2.0 ± 0.6; Total weed taxa 5

Altitude: c. 1100 m.

Diagnostic Taxa: Shrubs *Epacris celata* (100), *Epacris gunnii* (100); **Herbs** *Brachyscome scapigera* (100), *Cotula alpina* (100), *Deyeuxia gunniana* (100), *Empodisma minus* (100), *Euphrasia collina* subsp. *paludosa* (100), *Stylidium montanum* (100), *Bulbine bulbosa* (67), *Hydrocotyle sibthorpioides* (67), *Lomandra* sp. aff. *oreophila* (67), *Luzula flaccida* (67), *Poa clivicola* (67), *Poa sieberiana* (67), *Themeda triandra* (67)

Other Common Taxa *Asperula gunnii* (67), *Brachyscome decipiens* (67), *Carex breviculmis* (67), *Gonocarpus micranthus* (67), *Hakea microcarpa* (67), *Hypericum japonicum* (67), *Poranthera microphylla* (67)

Significant Taxa: *Dillwynia palustris*, *Diuris pedunculata*, *Prasophyllum bagoensis*, *P.* sp. aff. *canaliculatum* (McPhersons Plain)

Weeds: *Hypochaeris radicata* (67), *Trifolium repens* (67), *Cerastium vulgare* (33), *Holcus lanatus* (33), *Poa pratensis* (33) .

Group XII – Upper Murrumbidgee dwarf heathland

Community 43: Bossiaea riparia dwarf heathland

Equivalent communities: Nil

Bossiaea riparia dwarf heathland is restricted to the rocky slopes above the upper Murrumbidgee River, and a few of its tributaries (in the vicinity of Currango Plain and Tantangara Dam). The community is characterised by an extensive cover of the shrub *Bossiaea riparia* and much exposed rock. The associated flora is variable and may depend on the amount of soil present and the composition of the surrounding vegetation. Despite its variability, the community has few affinities with other communities. Five species were restricted to it or were very rare in other communities (*Bossiaea riparia*, *Cryptandra amara*, *Daviesia mimosoides* subsp. *acris*, *Mirbelia oxylobioides*, *Patersonia longifolia*). At least one example was burnt in 2003. Regeneration there has been slow. Some examples near Tantangara Dam are very sparsely vegetated and species-poor, perhaps indicating past disturbance. Curiously, aerial photographs taken in 1970 show that some areas now occupied by this community were largely bare at that time. Any attempts to revegetate the remaining bare slopes below Tantangara Dam should be made in the knowledge that the natural community has a sparse plant cover and the community is rare and significant. *Bossiaea riparia* should be the main component of any revegetation plan and seed for the work should be sourced from the immediate area.

No. quadrats 4; Native taxa / quadrat 24.3 ± 3.3; Total native taxa 65; Weeds /quadrat 3.5 ± 1.3; Total weed taxa 10

Altitude: 1220 – 1250 – 1280 m.

Diagnostic Taxa: Shrubs *Bossiaea riparia* (100), *Hakea microcarpa* (100), *Pimelea linifolia* subsp. *caesia* (100), *Cryptandra amara* (75), *Dillwynia prostrata* (50), *Leucopogon fraseri* (50); **Herbs** *Themeda triandra* (100), *Luzula flaccida* (75), *Calotis glandulosa* (50), *Euchiton collinus* (50), *Microlaena stipoides* (50), *Poa clivicola* (50), *Podolepis jaceoides* (50)

Other Common Taxa: *Carex breviculmis* (75), *Microseris* sp. 2 (50), *Rhodanthe anthemoides* (50), *Senecio pinnatifolius* var. *alpinus* (50), *Trisetum spicatum* (50)

Significant Taxa: *Bossiaea riparia*, *Calotis glandulosa*, *Rutidosis leiolepis*

Weeds: *Hypochaeris radicata* (75), *Acetosella vulgaris* (50), *Vulpia bromoides* (50), *Agrostis capillaris* (25), *Aira caryophyllea* (25), *Anthoxanthum odoratum* (25), *Aphanes arvensis* (25), *Cerastium glomeratum* (25), *Myosotis discolor* (25), *Trifolium campestre* (25)



Fig. 15. *Hovea montana - Poa phllipsiana* open heathland (Community 32) on Mt Buffalo, Victoria. Shrubs occurring with *H. montana* here are *Olearia algida* and, by rocks, *Grevillea australis*. Flowering *Xerochrysum subundulatum* is apparent.

Group XIII – Baw Baw open heathlands

Community 44: Pultenaea muelleri open heathland

Equivalent communities: Baw Baw dry alpine shrubland, subcommunities 5.1 & 5.2 (Walsh et al. 1984).

This community is confined to the Baw Baw Plateau where it is common, usually in rocky areas with some northerly aspect on higher parts of the range between Mts Whitelaw and Erica. A diverse, often dense shrub layer to 1 m high or more is characteristic, usually comprising *Pultenaea muelleri, Olearia phlogopappa, Orites lancifolia* and *Ozothamnus secundiflorus*, and often with other shrubs more characteristic of the adjacent woodlands dominated by *Eucalyptus pauciflora* subsp. *acerina*. A 'halo' of this community is also common on the rim of depressions surrounding Communities 1 and 45. Although somewhat ecotonal, it is floristically well defined. While not entirely confined to the Baw Baw plateau, the shrubs *Tasmannia vickeriana* and *Trochocarpa clarkei* are commoner here than elsewhere in the Alps. A few examples of this community have been modified (slashed and/or cleared) within the Baw Baw ski resort area, but otherwise the community is fully contained within the Baw Baw National Park and is not subject to significant threatening processes.

No. quadrats 17; Native taxa / quadrat 21.6 ± 1.2; Total native taxa 78; Weeds /quadrat 2.6 ± 0.3; Total weed taxa 7

Altitude: 1320 – 1415 – 1540 m.

Diagnostic Taxa: Shrubs *Pultenaea muelleri* (82), *Olearia algida* (65), *Olearia phlogopappa* var. *flavescens* (59), *Orites lancifolia* (53), *Pimelea alpina* (53), *Ozothamnus secundiflorus* (47), *Trochocarpa clarkei* (47), *Ozothamnus* sp. 1 (29), *Leucopogon maccraei* (18), *Olearia megalophylla* (18), *Tasmannia vickeriana* (18), *Leucopogon gelidus* (12); **Herbs** *Carex breviculmis* (100), *Hydrocotyle algida* (88), *Oreomyrrhis eriopoda* (88), *Stylidium* spp. (88), *Viola hederacea* (88), *Celmisia* spp. (82), *Senecio gunnii* (72), *Gonocarpus montanus* (71), *Poa hiemata* (71), *Luzula modesta* (65), *Prasophyllum* spp. (53), *Lycopodium fastigiatum* (47), *Podolepis robusta* (41), *Poranthera microphylla* (35), *Leptinella filicula* (29), *Plantago alpestris* (29), *Scaevola hookeri* (24)

Other Common Taxa: *Asperula gunnii* (76), *Poa fawcettiae* (47), *Rytidosperma nudiflorum* (41), *Scleranthus biflorus* (41)

Weeds: *Hypochaeris radicata* (94), *Acetosella vulgaris* (65), *Cerastium vulgare* (59), *Aira caryophyllea* (18), *Poa pratensis* (18), *Agrostis capillaris* (6), *Trifolium repens* (6)

Community 45: Epacris petrophila open heathland

Equivalent communities: Baw Baw damp alpine heathland, subcommunity 8.1 (Walsh et al. 1984).

Largely confined to the Baw Baw plateau with minor occurrences on Lake Mountain, this generally low-growing community is invariably associated with Community 1 (Baw Baw – Lake Mountain wet heathland), but occupying higher sites. The community comprises a number of species of both the wet heathland community below and Community 44 upslope, but often includes *Asterolasia trymalioides, Grevillea australis* and *Lobelia pedunculata*, species which generally are not encountered in adjacent communities. The abundance of *Epacris petrophila* here is of interest as it is otherwise a rare species in the Victorian alps, but locally common in parts of Kosciuszko National Park (e.g. Communities 4, 35, 37, 39) where it occurs at considerably higher altitudes.

No. quadrats 8; Native taxa / quadrat 21.5 ± 1.7; Total native taxa 60; Weeds /quadrat 0.3 ± 0.0; Total weed taxa 1

Altitude: 1310 – 1380 – 1480 m.

Diagnostic Taxa: Shrubs *Asterolasia trymalioides* (100), *Epacris petrophila* (100), *Grevillea australis* (100), *Pimelea alpina* (88), *Olearia algida* (63), *Orites lancifolia* (63), *Ozothamnus* sp. 1 (63), *Trochocarpa clarkei* (38), *Exocarpos nanus* (33); **Herbs** *Asperula gunnii* (100), *Empodisma minus* (100), *Poa hiemata* (100), *Podolepis robusta* (88), *Celmisia* spp. (75), *Lobelia pedunculata* (63), *Gentianella* spp. (50), *Xerochrysum subundulatum* (50), *Rhytidosporum procumbens* (25)

Other Common Taxa: *Carex breviculmis* (75), *Luzula modesta* (50), *Oreomyrrhis eriopoda* (50)

Weeds: *Cerastium vulgare* (25)

Group XIV – high altitude closed heathlands

Community 46: Nematolepis ovatifolia – Prostanthera cuneata closed heathland

Equivalent communities: part of *Oxylobium ellipticum – Podocarpus alpinus* alliance (Costin 1954); *Phebalium ovatifolium* association (McVean 1969).

A tall, closed heathland (to about 1.5 m in height) dominated by one or more of *Nematolepis ovatifolia, Orites lancifolia*, and *Prostanthera cuneata* occurs close to the treeline and on isolated rocky outcrops between Mt Kosciuszko and Mt Jagungal, with outliers in the upper Tumut River valley and Kiandra. The understorey is often sparse, although any gaps in the canopy are commonly more diverse and dominated by tussock grass species (mostly *Poa fawcettiae* and *P. hiemata*). This community may be distinguished from Community 23 by its taller stature, closed structure, greater shrub diversity and lesser understorey diversity. Community 46 is also commonly found closer to the treeline. This community is common and under little threat, although small areas are subject to clearing applications for skiing development. The northern outliers have special significance: that in the upper Tumut Valley contains the northern-most population of *Nematolepis ovatifolia* and that at Kiandra contains the northern-most population of *Phebalium squamulosum* subsp. *alpinum*. Much of the community was burnt in 2003 but regeneration seems to have occurred of most species (Walsh & McDougall 2005).



Fig. 16. Community 34 is a very open woodland dominated by *Eucalyptus lacrimans*. The understorey may be open heathland (as shown here on Long Plain) or grassland. This community is found on isolated knolls within subalpine plains or spurs extending from the Snow Gum woodland above.

No. quadrats 21; Native taxa / quadrat 18.0 ± 1.5; Total native taxa 107; Weeds /quadrat 0.8 ± 0.1; Total weed taxa 4

Altitude: 1420 – 1850 – 2040 m.

Diagnostic Taxa: Shrubs *Nematolepis ovatifolia* (81), *Olearia brevipedunculata* (76), *Prostanthera cuneata* (76), *Grevillea australis* (57), *Melicytus* sp. aff. *dentatus* (57), *Pimelea alpina* (48), *Orites lancifolia* (33), *Oxylobium ellipticum* (24), *Ozothamnus secundiflorus* (19), *Pimelea ligustrina* (19); **Herbs** *Viola betonicifolia* (62), *Poa hiemata* (57), *Poa fawcettiae* (48), *Erigeron nitidus* (43), *Euphrasia collina* subsp. *diversicolor* (24), *Helichrysum scorpioides* (19), *Poa ensiformis* (19)

Other Common Taxa: *Asperula gunnii* (52), *Carex breviculmis* (52), *Craspedia* spp. (*aurantia, jamesii*) (48)

Weeds: *Acetosella vulgaris* (67), *Cirsium vulgare* (5), *Festuca rubra* (5), *Hypochaeris radicata* (5)

Community 47: Bogong High Plains *Phebalium squamulosum – Bossiaea foliosa* closed heathland

Equivalent communities: *Phebalium-Bossiaea* heathland, Unit 2 (McDougall 1982).

Community 47 occurs throughout the Bogong High Plains on sites with shallow soil, often near the treeline or on lower rocky summits and ridges (Fig. 18). It may be dominated by *Prostanthera cuneata*, *Bossiaea foliosa* or *Orites lancifolia* (or any combination of these species). Tall shrubs such as *Phebalium squamulosum* subsp. *alpinum*, *Olearia phlogopappa* var. *flavescens* and *Ozothamnus alpinus* are occasional components. *Melicytus* sp. aff. *dentatus* and *Hovea montana* are commonly found beneath the upper shrub canopy with a sparse cover of herbs, of which *Poa hothamensis* is generally the most abundant. Shrub cover is often close to 100% whereas understorey cover may be minimal. The shrub canopy is usually 1 to 1.5 m in height. The community is common and widespread within a small geographic range. It is often the subject of slashing for ski slope maintenance in the resorts of Falls Creek and Mt Hotham.

No. quadrats 35; Native taxa / quadrat 16.5 ± 0.8; Total native taxa 73; Weeds /quadrat 0.9 ± 0.1; Total weed taxa 3

Altitude: 1610 – 1730 – 1830 m.

Diagnostic Taxa: Shrubs *Melicytus* sp. aff. *dentatus* (71), *Phebalium squamulosum* subsp. *alpinum* (71), *Hovea montana* (60), *Prostanthera cuneata* (51), *Bossiaea foliosa* (49), *Orites lancifolia* (49), *Grevillea australis* (46), *Olearia phlogopappa* var. *flavescens* (40), *Olearia frostii* (37), *Ozothamnus alpinus* (14); **Herbs** *Poa hothamensis* (94),



Fig. 17. An aerial view of Community 40 (*Epacris gunnii – Chionohebe pulvinatus* feldmark) at Northcote Pass on the Kosciuszko Main Range showing the mosaic of *Epacris gunnii* and rocky pavement. The walking track bisecting the community here is interrupting the slow movement of shrubs across the ridge.

Asperula gunnii (83), *Viola betonicifolia* (83), *Acaena novae-zelandiae* (57), *Leptinella filicula* (46), *Carex hebes* (43), *Helichrysum nitidolepis* (26), *Lagenophora stipitata* (17)

Other Common Taxa: *Carex breviculmis* (71), *Celmisia* spp. (46)

Weeds: *Acetosella vulgaris* (80), *Hypochaeris radicata* (9), *Cerastium glomeratum* (6)

Group XV – Central Victorian Alps rocky open heathlands

Community 48: Podolobium alpestre - Euryomyrtus ramosissima open heathland

Equivalent communities: Low alpine shrubland, subcommunity 2.2; Sparse rocky alpine heathland, subcommunity 3.1 (Walsh et al. 1984).

This is a structurally and ecologically distinctive community confined to exposed rocky peaks and associated cliff lines of moderately high altitude in an area bounded approximately by Mt Cobbler, The Viking, Mt Howitt and Mt McDonald in Victoria. The substrate is derived from Palaeozoic sediments and is sometimes shaly. Soils are shallow, often confined to crevices in the rock, and runoff is high. Species in this community must be drought-tolerant to survive the extreme exposure over summer. The community is a sparse heathland with any or all of a mix of shrubs to c. 1 m high with the cliff-specialist graminoids *Poa fawcettiae*, *Austrodanthonia alpicola* and *Luzula novae-cambriae*. *Joycea pallida*, usually a tussock of lower altitudes is a surprising occasional component of this community. Some sites supporting this community are prone to trampling by hikers and sightseers, particularly on accessible summits like Mt Buller, and to erosion on slopes where the Alpine Walking Track passes through the community. Levels of visitation are generally not so high as to cause anything but localised damage.

No. quadrats 22; Native taxa / quadrat 14.6 ± 0.7; Total native taxa 86; Weeds /quadrat 0.7 ± 0.2; Total weed taxa 4

Altitude: 1380 – 1525 – 1800 m.

Diagnostic Taxa: Shrubs *Podolobium alpestre* (68), *Euryomyrtus ramosissima* (59), *Acacia siculiformis* (45), *Kunzea muelleri* (41), *Phebalium squamulosum* subsp. *alpinum* (32), *Crowea exalata* (32), *Micrantheum hexandrum* (32), *Westringia senifolia* (32), *Acacia alpina* (14), *Daviesia ulicifolia* (14), *Grevillea victoriae* subsp. *victoriae* (14); **Herbs** *Poa fawcettiae* (95), *Leucochrysum albicans* subsp. *alpinum* (59), *Bulbine bulbosa* (50), *Luzula novae-cambriae* (50), *Brachyscome spathulata* (45), *Austrodanthonia eriantha* (32), *Austrodanthonia alpicola* (27), *Joycea pallida* (18), *Lomandra oreophila* (18)

Other Common Taxa: *Carex breviculmis* (73), *Microseris* sp. 2 (41)

Weeds: *Hypochaeris radicata* (36), *Acetosella vulgaris* (27), *Aira caryophyllea* (5), *Spergularia media* (5)

Community 49: Snowy Range – Mt Buffalo *Kunzea muelleri* heathland

Equivalent communities: *Kunzea ericifolia* heathland, subcommunities 4.1, 4.2 & 4.3 (Walsh et al. 1984).

A low heathland of relatively dry, rocky sites of gentle gradient on the Snowy Range, Mt Speculation, Mt Buller, The Bluff and Mt Buffalo in Victoria (Fig. 19). The root-suckering shrub *Kunzea muelleri* is ubiquitous in this community, usually with a high cover which results in a relatively low species diversity. The shrub *Micrantheum hexandrum* is relatively uncommon throughout the Alps (often commoner beside streams below the treeline), but is frequent through the range of this community and helps to distinguish it from other, higher-altitude *Kunzea muelleri* heathlands of the Bogong High Plains and Kosciuszko areas. The tussock grasses, *Poa fawcettiae* and *Austrostipa nivicola* are common components and indicative of its dry environment. The tangled, shrubby nature of this community generally does not invite traverse by cattle or people so damage is usually slight and localised, and is reflected by the low weed abundance. Recovery of *Kunzea muelleri* after the 2003 fires on Mt Buffalo has been slow, by both seed and root sucker. It would appear that this shrub is relatively slow growing and that extensive areas are probably very old. Traffic across recovering areas of this community should be discouraged until establishment is well underway.

No. quadrats 17; Native taxa / quadrat 17.4 ± 1.3; Total native taxa 87; Weeds /quadrat 0.6 ± 0.1; Total weed taxa 2

Altitude: 1380 – 1545 – 1740 m.

Diagnostic Taxa: Shrubs *Kunzea muelleri* (100), *Hovea montana* (65), *Pimelea alpina* (59), *Euryomyrtus ramosissima* (29), *Micrantheum hexandrum* (24); **Herbs** *Carex breviculmis* (94), *Poa fawcettiae* (82), *Brachyscome spathulata* (71), *Austrostipa nivicola* (53), *Chiloglottis valida* (24), *Rhytidosporum procumbens* (24)

Other Common Taxa: *Asperula gunnii* (71), *Microseris* sp. 2 (53), *Grevillea australis* (47), *Leptorhynchos squamatus* subsp. *alpinus* (47), *Celmisia* spp. (41), *Craspedia* spp. (41), *Leucopogon* spp. (41), *Prasophyllum* spp. (41)

Weeds: *Hypochaeris radicata* (47), *Acetosella vulgaris* (12)

Community 50: Olearia phlogopappa – Podolobium alpestre closed heathland

Equivalent communities: Low alpine shrubland, subcommunity 2.1 (Walsh et al. 1984).

Community 50 is generally a dense shrubby community of rock outcrops, rocky slopes and gullies, resembling in many respects *Podocarpus lawrencei* heathland (Community 54), but lacking the dominant of that community. It has been recorded mainly from the Crosscut Saw between Mts Howitt and Cobbler, the high ridge between Mt Howitt and The Bluff and on Mt Buller with an outlier on Mt Cobberas 1. The rocks are mainly sedimentary, but igneous on Mt Buffalo and Mt Cobberas. The low diversity and near absence of herbaceous species is indicative of the rocky substrate permitting few footholds for shallow-rooted species. Most dominant species in this community are obligate seed regenerators, as evidenced by the response to the fires of January 2003. This suggests that, to some extent, the distribution and abundance of this community may be linked to past fire history. Elevated rocky sites like this are subject to lightning strikes, and small local fires may result. Because of their exposure, slope and preponderance of obligate seed regenerators (which are generally slower to recover than resprouters), areas of this community recovering from the 2003 fires are prone to loss of the small amount of soil present in heavy rainfall events. There is little that is practicable to protect these sites, but where possible, access to foot traffic should be restricted.

No. quadrats 6; Native taxa / quadrat 18.5 ± 2.8; Total native taxa 58; Weeds /quadrat 1.3 ± 0.2; Total weed taxa 3

Altitude: 1660 – 1695 – 1760 m.

Diagnostic Taxa: Shrubs *Olearia phlogopappa* var. *flavescens* (100), *Podolobium alpestre* (83), *Pimelea axiflora* subsp. *alpina* (67), *Tasmannia xerophila* (67); **Herbs** *Stellaria pungens* (83), *Polystichum proliferum* (50), *Wahlenbergia gloriosa* (33)

Other Common Taxa: *Acaena novae-zelandiae* (50), *Asperula gunnii* (50), *Hovea montana* (50), *Leucopogon hookeri* (50), *Oreomyrrhis eriopoda* (50), *Poa fawcettiae* (50), *Trisetum spicatum* (50)

Weeds: *Acetosella vulgaris* (83), *Hypochaeris radicata* (50), *Epilobium ciliatum* (17)



Fig. 18. Closed heathland dominated by *Prostanthera cuneata*, *Orites lancifolia* and *Phebalium squamulosum* var. *alpinum* in Rocky Valley on the Bogong High Plains (Community 47). This community is generally found on the upper slopes of subalpine valleys and may extend into adjoining Snow Gum woodland.



Fig. 19. Snowy Range – Mount Buffalo *Kunzea muelleri* heathland (Community 49) on Mt Buffalo. Shrubs associated with *K. muelleri* here include *Acacia alpina*, *Boronia algida*, *Grevillea australis* and *Micranthemum hexandrum*.

Group XVI – rocky outcrop open heathland

Community 51: Austrodanthonia alpicola – Grevillea australis open heathland

Equivalent communities: *Brachycome nivalis – Danthonia alpicola* alliance (Costin 1954); *Poa hothamensis* (rocky) grassland, Unit 13 (McDougall 1982); *Brachyscome-Austrodanthonia* tall alpine herbfield (Costin et al. 2000).

Community 51 occurs on cliffs and other rocky outcrops from Mt Buller to the Bogong High Plains in Victoria and from the Main Range to Kiandra in New South Wales. Although described in the past as a grassland dominated by *Austrodanthonia alpicola*, this community often has a significant component of shrubs (mostly *Grevillea australis*, *Leucopogon montanus* or *Podocarpus lawrencei*). Plant cover in general is minimal. Despite the occurrence of local endemics (e.g. *Poa hothamensis* and *Euphrasia crassiuscula* on the Bogong High Plains), this community spans geographic areas, perhaps because of the large number of character species that are commonly found throughout its range (e.g. *Austrodanthonia alpicola*, *Brachyscome nivalis*, *Brachyscome rigidula*, *Crassula sieberiana*, *Deyeuxia monticola*, *Luzula novae-cambriae*) but rarely in other communities. Examples on the cliffs above Blue Lake in Kosciuszko National Park are possibly threatened by rock climbing. Examples elsewhere may be damaged by tourists climbing rocky outcrops for better views but the overall threat to the community from these activities is currently low.

No. quadrats 32; Native taxa / quadrat 21.2 ± 0.9; Total native taxa 132; Weeds /quadrat 1.5 ± 0.1; Total weed taxa 4

Altitude: 1420 – 1790 – 2180 m.

Diagnostic Taxa: Shrubs *Grevillea australis* (59), *Leucopogon* spp. (*hookeri*, *montanum*) (59), *Pimelea axiflora* subsp. *alpina* (31), *Podocarpus lawrencei* (22); **Herbs** *Poa hothamensis* (72), *Austrodanthonia alpicola* (50), *Brachyscome rigidula* (50), *Crassula sieberiana* (50), *Trisetum spicatum* (50), *Luzula novae-cambriae* (47), *Brachyscome nivalis* (41), *Epilobium billardieranum* (41), *Polystichum proliferum* (31), *Aciphylla glacialis* (28), *Leucochrysum albicans* subsp. *alpinum* (28), *Deyeuxia monticola* (25), *Ewartia nubigena* (22), *Scleranthus singuliflorus* (22), *Euphrasia crassiuscula* (19), *Geranium potentilloides* (19), *Sclerorhus diander* (19), *Chrysocephalum semipapposum* (16), *Wahlenbergia gloriosa* (9), *Austrodanthonia oreophila* (6)

Other Common Taxa: *Carex breviculmis* (78), *Craspedia* spp. (*aurantia*, *jamesii*) (56), *Celmisia* spp. (*costiniana*, *pugioniformis*) (50), *Viola betonicifolia* (41)

Significant Taxa: *Euphrasia crassiuscula* subsp. *glandulifera*

Weeds: *Acetosella vulgaris* (63), *Hypochaeris radicata* (41), *Taraxacum officinale* (16), *Spergularia rubra* (3)

Group XVII – ACT rocky outcrop mallee shrubland

Community 52: Eucalyptus debeuzevillei mallee shrubland

Equivalent communities: Group 15 (Helman et al. 1988).

This community is a shrubland with scattered mallee *Eucalyptus debeuzevillei*. It is restricted to the rocky upper slopes of peaks such as Mt Scabby and Mt Kelly on the ACT / NSW border. The community is characterised by its high diversity of shrub species, three of which (*Epacris robusta*, *Phebalium squamulosum* subsp. *azothamnoides* and *Leptospermum namadgiensis*) are not known from other treeless communities, and low diversity of herbs.

No. quadrats 4; Native taxa / quadrat 19.8 ± 3.6; Total native taxa 51; Weeds /quadrat 1.0 ± 0.0; Total weed taxa 3

Altitude: 1720 – 1780 – 1810 m.

Diagnostic Taxa: Shrubs *Eucalyptus debeuzevillei* (100), *Oxylobium ellipticum* (100), *Podolobium alpestre* (100), *Epacris robusta* (75), *Phebalium squamulosum* subsp. *azothamnoides* (75), *Kunzea muelleri* (50), *Leptospermum namadgiensis* (50), *Podocarpus lawrencei* (50), *Westringia lucida* (50); **Herbs** *Viola improcera* (100), *Caladenia alpina* (50), *Derwentia perfoliata* (50), *Helichrysum scorpioides* (50)

Other Common Taxa: *Luzula* spp. (75), *Asterolasia trymalioides* (50), *Leucopogon hookeri* (50), *Pimelea linifolia* subsp. *caesia* (50), *Poa phillipsiana* (50), *Senecio pinnatifolius* var. *alpinus* (50), *Stellaria pungens* (50)

Significant Taxa: *Viola improcera*

Weeds: *Acetosella vulgaris* (50), *Hypochaeris radicata* (50), *Taraxacum officinale* (25)

Group XVIII – boulder heathlands

Community 53: Podocarpus lawrencei – Epacris paludosa closed heathland

Equivalent communities: *Baeckea gunniana – Richea continentis* association (McVean 1969)

Community 53 is a closed heathland that straddles many small creeks in Kosciuszko National Park, often where water flows amongst large boulders (e.g. Guthrie Creek, Hedley Tarn, Mt Selwyn), and is occasionally found at the edge of large waterways (e.g. Tooma River). In the classification, only one quadrat from Victoria (Lankeys Plain) was included but the community has probably been undersampled there as examples are often narrow and intergrade imperceptibly with other communities. The community is dominated by tall shrubs, commonly *Podocarpus lawrencei*, *Epacris paludosa*, *Tasmannia xerophila* and *Baeckea utilis*. Herbs are generally sparse under the dense shrub canopy. This community does not appear to be under threat at present, although examples are found in ski resorts.

No. quadrats 13; Native taxa / quadrat 22.2 ± 2.4; Total native taxa 102; Weeds /quadrat 0.8 ± 0.5; Total weed taxa 6

Altitude: 1280 – 1680 – 1950 m.

Diagnostic Taxa: Shrubs *Podocarpus lawrencei* (92), *Epacris paludosa* (75), *Tasmannia xerophila* (75), *Baeckea utilis* (67), *Olearia phlogopappa* var. *flavescens* (58), *Pimelea bracteata* (58), *Oxylobium ellipticum* (42), *Ozothamnus secundiflorus* (33), *Leucopogon maccraei* (17); **Herbs** *Acaena novae-zelandiae* (92), *Blechnum penna-marina* (92), *Viola betonicifolia* (83), *Epilobium gunnianum* (50), *Geranium potentilloides* (42), *Gonocarpus montanus* (42), *Helichrysum rutidolepis* (33), *Polystichum proliferum* (33), *Chionochloa frigida* (25), *Dianella tasmanica* (25), *Huperzia australiana* (25)

Other Common Taxa: *Poa hiemata* (50), *Asperula gunnii* (42), *Empodisma minus* (42), *Richea continentis* (42)

Weeds: *Acetosella vulgaris* (38), *Cerastium glomeratum* (8), *Cirsium vulgare* (8), *Festuca rubra* (8), *Hypochaeris radicata* (8), *Taraxacum officinale* (8)

Community 54: Podocarpus lawrencei closed heathland

Equivalent communities: part of *Oxylobium ellipticum – Podocarpus alpinus* alliance (Costin 1954); *Podocarpus lawrencei* association (McVean 1969); *Podocarpus* heathland, Unit 1 (McDougall 1982); *Podocarpus* heathland, subcommunity 1.1 (Walsh et al. 1984).

Closed heathland dominated by *Podocarpus lawrencei* occurs in areas of minimal soil development and abundant large rocks (Fig. 20). The community is found in Victoria (on the Bogong High Plains, Mt Hotham area, Mt Howitt, Mt Buffalo, Cobberas and Crosscut Saw) and New South Wales (between Mt Kosciuszko and Mt Jagungal with an outlier in the Happy Jacks Plain area) but apparently not in the ACT. Examples have been recorded on metamorphic rock, where the dominant species, *Podocarpus lawrencei*, layers over large rock slabs, on granite boulder streams and outcrops, and on basalt scree. Species richness is commonly low and in sites with large rocks and no exposed soil there were often only one or two species per quadrat. After the 2003 fires, the diversity of many *Podocarpus lawrencei* heathlands increased. *Pelargonium helmsii*, a species rarely recorded prior to 2003, was found to be common in many burnt *Podocarpus lawrencei* heathlands in Kosciuszko National Park. A population of *Senecio velleioides*, normally a species of wet forest, was located in this community two years after the fire, at 1880 m a.s.l. on Blue Cow Mountain, the first record in treeless vegetation in the Australian Alps. *Podocarpus lawrencei* heathland is highly restricted and the primary habitat for the Mountain Pygmy Possum, an endangered mammal. Surveys of regeneration following the 2003 fires suggest that recovery of many stands will be slow and patchy, and some may not recover at all in the short term. Basal regeneration has been observed in some populations in the ACT and Cobberas (Carey et al. 2003, Tolsma et al. 2004) but none had been observed in populations in Kosciuszko National Park three years after the fires (McDougall and Broome unpublished data). Resprouting of partially burnt stems did occur throughout its range but it tended to be rare and much of the regeneration subsequently died. Seedlings were observed in the summer following the fire but these have been rare or patchy at some sites. At Mt Blue Cow, for instance, very few seedlings could be found in the summit area. Further downslope, seed germination did occur in the three snow-free seasons following the fire and seedlings were locally abundant. Supplementary planting of *Podocarpus lawrencei* may be necessary in the summit area of Mt Blue Cow if the community is to persist there with its structural dominant. This task will be very difficult because there is little soil in which to plant.

No. quadrats 24; Native taxa / quadrat 8.8 ± 1.2; Total native taxa 65; Weeds /quadrat 0.5 ± 0.3; Total weed taxa 6

Altitude: 1400 – 1745 – 2080 m.

Diagnostic Taxa: Shrubs *Podocarpus lawrencei* (100), *Pimelea ligustrina* (63), *Olearia phlogopappa* var. *flavescens* (46), *Tasmannia xerophila* (46), *Orites lancifolia* (38), *Neomatolepis ovatifolia* (17); **Herbs** *Polystichum proliferum* (50), *Uncinia flaccida* (17)

Weeds: *Acetosella vulgaris* (29), *Arenaria serpyllifolia* (4), *Cerastium vulgare* (4), *Hypochaeris radicata* (4), *Taraxacum officinale* (4), *Trifolium repens* (4)

Group XIX – boulder herbaceous communities

Community 55: *Carex appressa* sedgeland

Equivalent communities: Part of *Carex appressa* sedgeland, Unit 12 (McDougall 1982).

Carex appressa sedgeland occupies basalt block streams on the Bogong High Plains. Whilst this is also the habitat for Communities 54 and 56, Community 55 is found in block streams that are partly or largely covered with soil and where the habitat is moist. Species diversity is low and weeds are relatively common. Communities dominated by *Carex appressa* may also be found below the treeline in the Australian Alps. These appear to be floristically distinct and are not included in Community 55. Most or all examples of this community were burnt in the January 2003 fires. The long-term effects of the fires are currently unknown but in general, *Carex* species regenerate rapidly after fire due to their deep, fire-protected, rhizomes.

No. quadrats 3; Native taxa / quadrat 12.7 ± 1.5; Total native taxa 19; Weeds /quadrat 2.3 ± 0.3; Total weed taxa 5

Altitude: 1710 – 1735 – 1780 m.

Diagnostic Taxa: Herbs *Carex appressa* (100), *Blechnum penna-marina* (67), *Hydrocotyle sibthorpioides* (67), *Alchemilla* sp. (33)

Other Common Taxa: *Acaena novae-zelandiae* (67), *Epacris paludosa* (67), *Hypericum japonicum* (67), *Oreomyrrhis ciliata* (67), *Poa costiniana* (67), *Ranunculus victoriensis* (67)

Weeds: *Trifolium repens* (67), *Cerastium vulgare* (33), *Lotus corniculatus* (33), *Mimulus moschatus* (33), *Taraxacum officinale* (33)

Community 56: *Poa helmsii* grassland

Equivalent communities: Part of *Carex appressa* sedgeland, Unit 12 (McDougall 1982)

Poa helmsii grassland occupies rocky slopes of basalt areas on the western edge of the Bogong High Plains. Examples tend to be linear, possibly indicating that they inhabit soil-filled block streams. Sites are much drier than those of Community 55, which occurs in similar habitat. *Poa helmsii* is the dominant species of this species-poor community, although *Carex appressa* (the dominant of Community 55) is also present. Weeds are relatively common. Most or all examples of this community were burnt in the January 2003 fires. The effects of the fires are unknown, but generally, *Poa* species are rapid post-fire colonisers with plants either resprouting from protected shoots or establishing from seedlings.

No. quadrats 5; Native taxa / quadrat 12.4 ± 1.3; Total native taxa 24; Weeds /quadrat 2.0 ± 0.4; Total weed taxa 3.

Altitude: 1730 – 1755 – 1800 m.

Diagnostic Taxa: Herbs *Acaena novae-zelandiae* (100), *Carex appressa* (100), *Poa helmsii* (100), *Melicytus* sp. aff. *deutatus* (80), *Asperula pusilla* (40)

Other Common Taxa: *Poa costiniana* (60), *Stellaria pungens* (60), *Viola betonicifolia* (60)

Weeds: *Acetosella vulgaris* (100), *Taraxacum officinale* (60), *Trifolium repens* (40)

Significant Plant Communities

Whilst all plant communities of the treeless area in the Australian Alps are of high conservation significance, some communities are of especial significance because of their small extent or the high degree of threat operating on them. The following communities have either already been identified as threatened under environmental legislation or might be considered so using criteria similar to those used by the IUCN for individual species.

Peat-based wetlands.

The Montane Peatlands endangered ecological community listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) incorporates Communities 2, 3 and 8. Community 6 will probably be part of the listing when it

is present within Community 2. Across their range in NSW, peat communities have been greatly reduced in extent by grazing, peat mining, fire and changes to hydrological systems (Whinam & Chilcott 2002). The Alpine Bog Community listed under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) includes Communities 1, 2, 3 and 4. The chief threatening process for peat communities in the Australian Alps is physical damage by trampling leading to loss of cover and alteration of local hydrology which leads to channelling of waterflow through the bog. This alteration of drainage patterns within and immediately outside the bog reduces its water-holding capacity, which in turn accelerates the degradation process. Damaged bogs are often identified by deeply channelled streams. Pristine bogs typically have little or no free running water. Although most alpine areas in the Australian Alps are now protected from grazing, human foot traffic remains a significant damaging process in many areas. Some bogs remain unprotected from cattle grazing on the Nunniong Plateau, and trampling by feral horses is an increasing threat in the Nunniong-Cobberas areas in Victoria, and the Tantangara and upper Thredbo valley areas in NSW. Significant areas of bog have been lost through the creation of lakes or dams for hydroelectricity production.

Snowpatches.

The Alpine Snowpatch Community, which is listed under the Victorian FFG Act, includes Communities 17 and 20. Throughout the Australian Alps, these communities are extremely rare and highly susceptible to damage (in the past by cattle and presently by human foot traffic) and the consequent risk of erosion and/or incursion into the low grass/forb sward by shrubs. Because of their dependence on late-lying snowpacks, these communities are amongst the most likely to be affected by elevated temperatures due to the greenhouse effect. A future National listing of snowpatch



Fig. 20. *Podocarpus lawrencei* closed heathland (Community 54) is found in areas with a deep profile of fragmented rock (usually basalt or granite) and minimal soil. In some examples (especially on sites of low relief), rocks may be small (a few cm in diameter). More commonly, rocks are large boulders (to several m in diameter in granitic areas) or slabs (especially in metamorphic areas). Species diversity is low and *Podocarpus lawrencei* is the dominant in all examples. An outlier of the community near Happy Jacks Plain is shown – the edges were burnt in the 2003 fire. The rock type here is basalt.

communities might include Communities 12, 13, 17 and 20. It might also include Community 11 (*Celmisia sericophylla* herbfield), most examples of which are narrow strips within snowpatch vegetation.

Short alpine herbfield.

The *Caltha introloba* Herbland Community, which is listed under the Victorian FFG Act, is referable to Community 10 (short alpine herbfield) above. In Victoria it is regarded as threatened because of its extreme rarity, its susceptibility to change in local hydrology and to damage by trampling. It is known by a very few examples on the Bogong High Plains. Although more common in the Kosciuszko area between the Ramshead Range and Mt Jagungal, short alpine herbfield has a very small area of occupancy and is threatened by changes in hydrology, which may result from global climate change.

Fens.

Under the Victorian FFG Act definition, fens include both Community 6 and 8. In the Victorian Alps, permanent standing water is less common than it is in New South Wales. There are no natural lakes above the treeline and the largest pools are less than c. 0.5 ha, and usually under 100m² in extent. The main threat to fens in Victoria has been identified as physical disturbance, primarily by cattle. Since cattle will be excluded from the Alpine National Park, there will remain only a few fens on the Nunniong Plateau likely to be accessed by stock. Nonetheless, increasing feral horse and sambar deer numbers remain a threat to the community, and any of the processes that impinge on the hydrology of bogs (which are usually part of the same alpine wetland complex) are also likely to have impacts on fens. In NSW, fens are included in the Montane Peatlands endangered ecological community under the TSC Act.

Epaeris gunnii – Chionohebe pulvinatus *Feldmark.*

Although this community tends to develop on any eroded surface of suitable geology on the Kosciuszko Main Range, its overall extent is very small. It is threatened in places by trampling by bushwalkers, although this is minor at present (McDougall & Wright 2003). The community may face a much greater threat if predicted less severe climatic conditions allow the invasion of species from adjoining communities.

Podocarpus *closed heathland.*

This community is the primary habitat of the endangered Mountain Pygmy Possum (*Burramys parvus*). It occupies a very small area within the Australian Alps. Many examples were burnt in the fires of 2003. Regeneration of the dominant *Podocarpus lawrencei* has been variable but it will clearly take decades until the new cohort reaches reproductive maturity. Until that time, burnt patches are especially vulnerable to further fires and any other process that hinders the development of the dominant.

Epaeris eelata – Poa clivicola *open heathland.*

Community 42 has only been recorded on McPhersons Plain, west of Kosciuszko National Park. Although it probably also occurs on neighbouring treeless areas (Tomneys and Sparkes Plains), none is in a conservation reserve. Parts of McPhersons Plain are in State Forest lease, the remainder is freehold land. The State Forest lease is currently managed by the lessee for the protection of the significant species and vegetation of the Plain but there is no long-term security for these important values. The community supports two listed threatened species (*Diuris pedunculata* and *Prasophyllum bagoensis*) and several undescribed orchids that are probably of restricted distribution (David Jones, CSIRO, pers. comm.).

Themeda triandra – Leucochrysum albicans *grassland.*

This grassland is extremely localised, being restricted to areas of limestone in Kosciuszko National Park, principally Cave Creek (with minor occurrences at Yarrangobilly). It is especially vulnerable to weed invasion. The examples at Yarrangobilly were dominated by weeds following the 2003 fires and it is not clear if the native species will again attain dominance. The Cave Creek examples have less cover of weeds (even where they were burnt) but the diversity of weeds is great in the Cave Creek area and there is potential for further degradation of floristic values through weed spread. *Potentilla recta* and *Sedum acre* are significant threats.

Bossiaea riparia *dwarf heathland.*

Community 43 has a very small area of occupancy. Although there are few immediate threats to the community (small areas have been damaged by off-road vehicles), the main areas currently containing Community 43 at Gulf Plain were largely bare in 1970 (judging from aerial photos taken at that time). The reasons for the lack of vegetative cover are unknown but the community has clearly undergone major natural regeneration in recent times.

Poa hookeri *grassland.*

Grassland dominated by *Poa hookeri* (Community 31) is reasonably common in a few places in Kosciuszko National Park (e.g. Nungar Plain, Happy Jacks Plain). This grassland contains a large number of significant species but is under great threat. It appears to be a favoured food source for pigs and large patches of this community have been turned over in the last decade. It is not clear if damaged areas regenerate to Community 31 or to 30, the latter of which is the more common in Plains where Community 31 occurs.

Discussion

Although the treeless vegetation of the Australian Alps occupies a very small area (c. 160,000 ha), it has exceptional diversity – comprising 710 native plant taxa and 56 communities. Even at single locations there may be great

diversity. On the Kosciuszko Main Range, for instance, an area of 10,000 ha, 212 native taxa (Costin et al. 2000) and 18 plant communities (this study) have been recorded. McDougall & Walsh (2002) recorded almost 200 native taxa on one subalpine plain in Kosciuszko National Park (Nungar Plain).

The communities identified above are largely in accord with previous classifications; 46 of the communities have an analog. Ten new communities were identified, however, all in the subalpine portion of Kosciuszko National Park, where there had been very little floristic survey previously. Further survey of communities with a low sample size and great variation between quadrats (i.e. Communities 9, 33, 34, 35, 42, 43 and 52) is warranted to determine if these are variants of others or if there are additional unidentified communities within them.

The treeless areas have been intensively utilised since European settlement, initially as summer pastures but more recently as water catchments for electricity production and as tourist attractions both in winter and summer. The impact of that use is still obvious as slowly revegetating scars (e.g. the old steps from Rawsons Pass to Mt Kosciuszko), widespread infrastructure (e.g. roads, tracks, fences, ski lifts and powerlines) and the presence of exotic species, many of which were deliberately introduced. The treeless communities of the Australian Alps have demonstrated remarkable resilience from the effects of their many uses as they have following the fires of January 2003. It is not possible to foretell, however, how much greater pressure the communities can sustain.

Treeless plant communities have undergone considerable change over the past 70 years and are likely to be under increasing pressure in the future with predicted changes to mountain climate. Current models of global warming predict elevation of mean temperatures in south-eastern Australia and, most probably, the normal winter snowline. Changes in the abundance of alpine plant communities because of global warming have been predicted (Pickering & Armstrong 2003). There is certainly likely to be a contraction of treeless areas, since tree establishment is controlled by low temperature in the growing season (Harwood 1980, Slatyer 1989). The expansion of tree islands last Century is noticeable on aerial photographs of the Bogong High Plains and Kosciuszko National Park (McDougall 2003, unpublished data) but it is impossible to irrefutably attribute this spread to global warming. If there are significant reductions in rainfall and snowfall associated with global warming, some wetland and snowpatch communities may also contract. A major shift from grassland to heathland during the 20th Century was noted on the Bogong High Plains in areas grazed by cattle (McDougall 2003, Bruce et al. 1999) and in Kosciuszko National Park after 1970 in areas no longer grazed by domestic stock (McDougall unpublished data). The shift is therefore independent of grazing regime. Similar changes in arctic vegetation have been attributed to the effects of global warming (Sturm et al. 2001) and the global contraction of glaciers attest to the potency of this phenomenon. The broadscale extinction of alpine plant species because of global warming seems less likely in the short-term because very few species have such a narrow ecological and altitudinal tolerance, but it can be expected in the medium to long-term.

One consequence of increased mean temperatures may be the invasion of the alpine zone by weeds. Few weed species have successfully established and persisted in the alpine zone. Costin et al. (2000) noted 48 species as having been recorded on the Kosciuszko Main Range but only 14 of these had persisted. There is a significant inverse correlation between altitude and the number of weed species recorded in treeless vegetation in the Australian Alps (McDougall et al. 2005). Whilst this probably indicates that the mountain climate acts as a sieve of weeds, 43% of weed species recorded in treeless vegetation occur in the 400 m altitude band below the alpine zone. A small increase in mean temperature could facilitate the upward invasion of many new weed species.

Pressures from tourist activities on treeless vegetation may be managed but they will continue, such is the popularity of the high mountain environment. The task of land managers is to minimise or eliminate other pressures. Introduced herbivores having a demonstrable impact (e.g. pigs, rabbits and feral horses) should be eradicated where possible. Their spread and impact has increased noticeably in recent years and there is no reason to suggest these will not continue at an accelerated rate. The impact of hares should be assessed and control measures initiated if they are having a detrimental impact. The planting of non-indigenous plant species should not be permitted in the subalpine or alpine zone and consideration should be given to removing exotic species already planted in some ski resort gardens. Many species have escaped from ski resort gardens (McDougall & Appleby 2000) and, although some escapes have been successfully controlled (e.g. around Mt Buffalo Chalet), their management seems an unnecessary cost. In addition, the continual introduction of new species into gardens will invite a further suite of escapes, most of which have been selected for their capacity to grow in cold conditions.

Sound management of treeless vegetation in the Australian Alps has been based on long-term monitoring and research. With the rapid changes occurring in the vegetation from fire, climate change, and recovery from grazing, and the exceptional significance of the vegetation and flora, it is critical that the research programs set up with foresight by early mountain ecologists be continued and expanded to chart the rapid changes that are clearly occurring in the vegetation, and to react to them accordingly.

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Appendix 1. Vascular plants of treeless vegetation in the Australian Alps

The list was compiled from quadrats sampled and used in the current study, our incidental observations, the lists of Thompson & Gray (1981), Helman & Gilmour (1985) (vegetation groups 1, 3, 4, 5 & 6) and Helman et al. (1988) (vegetation groups 8, 10, & 12).

[1]Distribution: a = on the Australian mainland restricted to treeless vegetation in the Australian Alps (but may extend for a short distance into adjoining snow gum woodland), 1 = occurring in alpine vegetation in Tasmania (Kirkpatrick 1997), 2 = occurring in alpine vegetation in New Zealand (Mark & Adams 1995), 3 = occurring in other locations outside Australia; b = commonly occurring in treeless vegetation of the Australian Alps but present elsewhere (at lower elevation and / or beyond the Australian Alps); c = occurring rarely in treeless vegetation of the Australian Alps and more common in vegetation elsewhere. * = non-native species (listed only if recorded from natural vegetation).

Taxon	% quadrats	% communities	Distribution[1]
FERNS & FERN ALLIES			
Adiantaceae			
Cheilanthes austrotenuifolia			c
Cheilanthes distans			c
Pellaea falcata			c
Aspleniaceae			
Asplenium flabellifolium	0.8	11	b
Asplenium trichomanes subsp. *quadrivalens*			c
Pleurosorus rutifolius			c
Athyriaceae			
Cystopteris tasmanica			a[12]
Blechnaceae			
Blechnum fluviatale	0.2	2	c
Blechnum penna-marina subsp. *alpina*	4.1	31	b
Blechnum vulcanicum			a
Dennstaedtiaceae			
Pteridium esculentum			c
Dryopteridaceae			
Polystichum proliferum	5.1	35	b
Gleicheniaceae			
Gleichenia dicarpa			c
Grammitidaceae			
Grammitis poeppigiana			a[12]
Hymenophyllaceae			
Hymenophyllum peltatum			a
Isoetaceae			
Isoetes muelleri			c
Lycopodiaceae			
Huperzia australiana	1.4	9	a
Lycopodium fastigiatum	8.3	39	b
Lycopodium scariosum	0.6	6	a[12]
Ophioglossaceae			
Botrychium australe			b
Botrychium lunaria			a[1]
Ophioglossum lusitanicum subsp. *coriaceum*	2.1	13	b
Osmundaceae			
Todea barbara			c
CONIFERS			
Pinaceae			
**Pinus contorta*			
Podocarpaceae			
Podocarpus lawrencei	4.6	20	b
MONOCOTYLEDONS			
Amaryllidaceae			
**Narcissus pseudonarcissus*			
Anthericaceae			
Arthropodium milleflorum	5.2	31	b
Arthropodium minus	0.3	2	c
Arthropodium strictum			c
Caesia alpina	4.0	28	a
Thysanotus tuberosus subsp. *tuberosus*			c
Asphodelaceae			
Bulbine bulbosa	3.8	17	b
Bulbine aff. *glauca* (Nungar Plain)	0.2	4	a
Asteliaceae			
Astelia alpina var. *novae-hollandiae*	9.6	19	a
Astelia psychrocharis	1.7	9	a
Colchicaceae			
Burchardia umbellata			c
Wurmbea dioica	0.1	2	c
Cyperaceae			
Baumea acuta			c
Baumea gunnii	0.4	4	c
Carex alsophila	0.1	2	c
Carex appressa	6.0	33	b
Carex archeri			a[1]
Carex blakei	3.0	13	a
Carex breviculmis	56.2	87	b
**Carex buxbaumii*			
Carex canescens	1.6	15	a[13]
Carex capillacea	1.0	13	a[1]
Carex cephalotes	0.7	6	a[12]
Carex chlorantha	0.7	7	b
Carex echinata	1.1	11	a[23]

Carex fascicularis	0.1	2	c
Carex gaudichaudiana	26.3	48	b
Carex hebes	18.7	72	a
Carex hypandra	0.8	4	a[1]
Carex incomitata	0.4	4	c
Carex inversa	0.8	7	c
Carex iynx	0.1	2	c
Carex jackiana	4.1	30	a[3]
**Carex ovalis*			
Carex paupera	0.1	2	a
Carex raleighii	0.2	4	a[1]
Carex tereticaulis			c
Carpha alpina	1.1	7	a[123]
Carpha nivicola	8.3	20	a
Eleocharis acuta	0.2	2	c
Eleocharis gracilis	0.5	6	c
Eleocharis pusilla			c
Eleocharis sphacelata	0.1	2	c
Gahnia subaequiglumis			c
Isolepis alpina			a[1]
Isolepis aucklandica	5.4	15	b
Isolepis crassiuscula	5.3	19	b
Isolepis fluitans	0.5	7	c
Isolepis gaudichaudiana	0.1	2	a
Isolepis habra	0.5	6	b
Isolepis inundata			c
Isolepis montivaga	3.6	30	a[1]
Isolepis subtilissima	2.3	13	b
Lepidosperma curtisiae			c
Lepidosperma laterale	0.4	9	c
Oreobolus distichus	11.2	30	b
Oreobolus oxycarpus subsp. *oxycarpus*	2.1	9	a
Oreobolus pumilio subsp. *pumilio*	2.9	13	a[1]
Schoenus apogon	2.1	9	c
Schoenus calyptratus	5.7	37	a[1]
Uncinia compacta	0.2	2	a[1]
Uncinia flaccida	1.1	15	a[1]
Uncinia sinclairii			a[2]
Uncinia sulcata	0.4	4	a
Hypoxidaceae			
Hypoxis hygrometrica var. *hygrometrica*	2.1	7	b
Hypoxis hygrometrica var. *splendida*			a
Iridaceae			
Patersonia longifolia	0.1	2	c
Juncaceae			
Juncus alexandri subsp. *alexandri*	0.1	2	c
Juncus antarcticus	0.5	6	a[12]
**Juncus articulatus*	0.1	2	
Juncus australis	1.1	9	b
Juncus brevibracteus	0.9	9	a
Juncus bufonius	0.6	7	c
**Juncus bulbosus*			
**Juncus effusus*			
**Juncus ensifolius*			
Juncus falcatus	4.5	15	b
Juncus homalocaulis			c
Juncus phaeanthus	0.4	2	a
Juncus sandwithii	2.5	13	a[1]
Juncus sarophorus	0.2	2	c
Juncus subsecundus			c
**Juncus tenuis*			
Juncus thompsonianus	0.1	2	a
Juncus vaginatus			c
Luzula acutifolia subsp. *acutifolia*	0.7	7	a[1]
Luzula acutifolia subsp. *nana*	1.1	11	a
Luzula alpestris	4.1	35	a
Luzula atrata	2.0	11	a[1]
Luzula australasica subsp. *dura*	1.7	13	a
Luzula meridonalis var. *flaccida*	6.3	26	b
Luzula modesta	28.3	59	b
Luzula novae-cambriae	7.5	50	a[1]
Orchidaceae			
Caladenia alpina	1.4	20	b
Caladenia fitzgeraldii	0.2	2	c
Chiloglottis turfosa			a
Chiloglottis valida	1.6	11	b
Dipodium punctatum			c
Diuris monticola	4.6	20	a
Diuris pedunculata			c
Eriochilus cucullatus	0.9	11	c
Genoplesium turfosum			a
Microtis unifolia	0.1	2	c
Prasophyllum alpestre [a]	5.1	48	a[1]
Prasophyllum bagoensis			a
Prasophyllum sp. aff. *canaliculatum* (McPhersons Plain)			a
Prasophyllum candidum [a]			a
Prasophyllum montanum			a
Prasophyllum morganii			a
Prasophyllum nigropedium			a
Prasophyllum retroflexum [a]			a
Prasophyllum sphacelatum [a]	1.4	15	a
Prasophyllum tadgellianum [a]	1.2	15	a[1]
Pterostylis alpina			c
Pterostylis cycnocephala	0.2	6	c
Pterostylis dubia	0.1	2	c
Pterostylis furcata			c

Pterostylis monticola			c
Pterostylis nuttica			c
Spirantlies australis subsp. *australis*	0.1	2	c
Thelymitra aristata			c
Thelymitra cyanea	4.9	11	a
Thelymitra ixioides var. *ixioides*			c
Thelymitra megcalyptra			c
Poaceae			
Agrostis australiensis	1.1	9	a
Agrostis bettyae [b]	0.1	2	c
**Agrostis capillaris*	1.0	22	
Agrostis joyceae [b]			a
Agrostis muelleriana	3.5	31	a[12]
Agrostis parviflora	3.0	35	a[1]
Agrostis propinqua [b]			b
**Agrostis stolonifera*	0.3	6	
Agrostis thompsoniae [b]			a
Agrostis venusta	7.5	48	b
**Aira caryophyllea*	1.1	13	
**Aira elegantissima*	0.1	2	
**Aira praecox*			
**Alopecurus pratensis*			
**Anthoxanthum odoratum*	1.4	13	
**Apera interrupta*			
**Arrhenatherum elatius*			
Australopyron velutinum	6.5	44	a[1]
Austrodanthonia alpicola	3.0	17	a
Austrodanthonia eriantha	2.0	19	b
Austrodanthonia laevis	2.9	22	b
Austrodanthonia linkii var. *fulva*			c
Austrodanthonia longifolia			c
Austrodanthonia monticola	0.2	2	c
Austrodanthonia oreophila	0.5	7	a
Austrodanthonia penicillata	0.5	9	b
Austrodanthonia pilosa	5.4	24	b
Austrodanthonia racemosa var. *racemosa*	1.1	11	b
Austrofestuca eriopoda			c
Austrofestuca hookeriana	3.8	9	b
Austrostipa nivicola	5.3	26	a
**Bromus carthaticus*			
**Bromus diandrus*			
**Bromus hordeaceus*	0.1	2	
**Bromus madritensis*			
**Bromus molliformis*			
Chionochloa frigida	1.4	11	a
**Cynosurus cristatus*			
**Dactylis glomerata*			
Deschampsia caespitosa	1.5	11	b
Deyeuxia affinis	1.5	11	a
Deyeuxia brachyathera	1.6	26	a[1]
Deyeuxia carinata	1.2	15	a[1]
Deyeuxia contracta			c
Deyeuxia crassiuscula	4.2	41	a
Deyeuxia gunniana	1.0	6	b
Deyeuxia innominata	0.7	7	a[1]
Deyeuxia monticola var. *monticola*	5.1	44	b
Deyeuxia quadriseta	0.5	7	c
Deyeuxia scaberula			c
Deyeuxia talariata	0.1	2	b
Dichelachne crinita	0.6	9	c
Dichelachne micrantha	1.4	7	c
Dichelachne rara	0.1	2	c
Echinopogon ovatus			c
Elymus scaber sens. lat.	4.0	28	b
Eragrostis brownii			c
**Festuca arundinacea*			
Festuca asperula	0.9	6	b
Festuca muelleri	1.1	17	a
**Festuca rubra*	0.4	9	
Hierochloe redolens	2.0	20	b
Hierochloe submutica	0.3	7	a
**Holcus lanatus*	1.8	15	
**Hordeum glaucum*			
Joycea pallida	0.7	7	c
Koeleria macrantha			c
Lachnagrostis aemula	1.6	13	b
Lachnagrostis avenacea	0.2	4	c
Lachnagrostis meiouectes	0.5	7	a
**Lolium perenne*			
Microlaena stipoides var. *stipoides*	0.5	9	c
**Phleum pratense*	0.6	6	
**Poa annua*	0.1	2	
Poa clivicola	7.0	33	a[1]
Poa costiniana	40.4	70	a[1]
Poa ensiformis	0.3	2	c
Poa fawcettiae	30.8	74	a[1]
Poa helmsii	1.1	11	b
Poa hiemata	30.3	70	a[1]
Poa hookeri	2.4	7	b
Poa hothamensis var. *hothamensis*	13.7	33	a
Poa labillardierei var. *acris*			a[1]
Poa labillardierei var. *labillardieri*	1.6	13	b
Poa petrophila	1.7	13	b
Poa phillipsiana	6.9	37	a
**Poa pratensis*	2.5	17	
Poa saxicola	2.6	26	a[1]
Poa sieberiana var. *cyanophylla*	0.2	2	c
Poa sieberiana var. *lirtella*			c

Poa sieberiana var. *sieberiana*	0.5	6	c
Rytidosperma australe	0.2	2	a[12]
Rytidosperma nivicolum	4.7	24	a[1]
Rytidosperma nudiflorum	23.4	70	a[1]
Rytidosperma pumilum	0.2	2	a[2]
Rytidosperma vickeryae	0.2	2	a
Tetrarrhena turfosa			c
Themeda triandra (*T. australis*)	2.3	17	e
Trisetum spicatum subsp. *australiense*	23.9	69	b
**Vulpia bromoides*	1.3	17	
**Vulpia myuros*			
Phormiaceae			
Dianella admixta			e
Dianella sp. aff. *tasmanica*	0.7	9	b
Herpolirion novae-zelandiae	2.0	17	a[12]
Thelionema caespitosum			e
Potamogetonaceae			
Potamogeton cheesemanii			e
Restionaceae			
Baloskion australe	10.9	30	b
Empodisma minus	32.0	59	b
Xanthorrhoeaceae			
Lomandra longifolia var. *exilis*			e
Lomandra sp. aff. *oreophila* (McPherson's Plain NSW)	0.2	2	
Lomandra oreophila	2.5	13	a
DICOTYLEDONS			
Alseuosmiaceae			
Wittsteinia vacciniacea	1.0	2	e
Apiaceae			
Aciphylla glacialis	7.4	46	a
Aciphylla simplicifolia	10.2	41	a
Actinotus bellidioides			a
Actinotus moorei			a[1]
Daucus glochidiatus	0.2	4	e
Dichosciadium ranunculaceum var. *ranunculaceum*	0.3	2	a
Diplaspis nivis	4.0	13	a
Eryngium vesiculosum			e
Gingidia algens	0.2	2	a
Gingidia harveyana	0.2	6	a
Hydrocotyle algida	8.2	30	a
Hydrocotyle sibthorpioides	4.9	31	b
Hydrocotyle tripartita	1.1	7	b
Lilaeopsis polyantha	0.5	6	b
Oreomyrrhis argentea	4.2	15	a[1]
Oreomyrrhis brevipes	0.6	6	a
Oreomyrrhis ciliata	10.5	41	a[1]
Oreomyrrhis eriopoda	30.7	76	b
Oreomyrris pulvinifica	1.7	6	a
Oschatzia cuneifolia	2.5	13	a
Platysace lanceolata			e
Schizeilema fragoseum	0.5	7	a
Trachymene anisocarpa			e
Trachymene humilis subsp. *brevicaule*	2.2	19	a[1]
Trachymene humilis subsp. *humilis*	0.1	2	c
Araliaceae			
Polyscias sambucifolia			c
Asteraceae			
Abrotanella nivigena			a[3]
**Achillea millefolium*	0.2	4	
Argyrotegium fordianum	7.8	41	a[1]
Argyrotegium mackayi	6.6	41	a[1]
Argyrotegium nitidulum	1.6	13	a[2]
Argyrotegium poliochlorum	1.6	13	a[1]
Brachyscome aculeata	2.9	19	b
Brachyscome decipiens	19.0	48	b
Brachyscome graminea	0.2	2	b
Brachyscome nivalis	5.1	30	a
Brachyscome obovata	4.2	17	a
Brachyscome radicans	0.6	7	a[1]
Brachyscome rigidula	4.9	28	b
Brachyscome scapigera	12.0	37	b
Brachyscome spathulata subsp. *spathulata*	15.9	61	b
Brachyscome stolonifera	2.5	9	a
Brachyscome tadgellii			
Brachyscome sp. 1 (*sensu* Ross & Walsh 2003)	0.2	4	a
Brachyscome sp. 2 (*sensu* Ross & Walsh 2003)			a
Brachyscome sp. 3 (*sensu* Ross & Walsh 2003)	0.5	4	a
Calotis glandulosa	0.3	4	b
Calotis pubescens	0.1	2	a
Calotis scabiosifolia var. *integrifolia*	0.1	2	b
Cassinia aculeata			c
Cassinia longifolia			c
Cassinia monticola	3.8	22	a
Cassinia ochracea	0.1	2	a
Celmisia costiniana[c]	5.6	31	a
Celmisia latifolia[c]			a
Celmisia pugioniformis[c]	9.5	33	b
Celmisia sericophylla	0.6	4	a
Celmisia tomentella[c]	1.3	15	b
Celmisia sp. aff. *pugioiformis* (supalpine wetlands)[c]	0.3	4	b
Centipeda cunninghamii			c
Centipeda minima			c
Chrysocephalum apiculatum	0.3	4	e

Chrysocephalum semipapposum	2.2	13	b
**Cirsium arvense*			
**Cirsium vulgare*	1.0	13	
**Chondrilla juncea*			
**Conyza bonariensis*			
Cotula alpina	10.5	33	a[1]
Craspedia adenophora (sp. B *sensu* Costin et al. 2000)	0.7	13	a
Craspedia alba	0.5	4	a
Craspedia aurantia[d]	5.0	35	a
Craspedia canens			c
Craspedia coolaminica[d]	5.4	20	a[1]
Craspedia costiniana	2.6	19	a
Craspedia crocata[d]	2.2	19	a
Craspedia jamesii[d]	9.2	39	a
Craspedia lamicola	1.1	15	a
Craspedia leucantha			a
Craspedia maxgrayii	3.3	20	a
Craspedia paludicola			c
**Crepis capillaris*	0.9	9	
Cymbonotus preissianus	0.5	7	b
Erigeron bellidioides	11.8	59	b
Erigeron conyzoides			a
Erigeron nitidus	10.3	46	a
Erigeron paludicola	6.7	17	a
Erigeron setosus	0.6	6	a
Erigeron tasmanicus			a[1]
Euchiton collinus	4.9	22	b
Euchiton gymnocephalus			c
Euchiton involucratus	0.8	4	b
Euchiton traversii	1.3	11	a[12]
Euchiton umbricola	0.1	2	b
Ewartia nubigena	4.8	26	a
Helichrysum adenophorum var. *waddelliae*			b
Helichrysum leucopsideum	0.1	2	b
Helichrysum rutidolepis	5.4	37	b
Helichrysum scorpioides	2.0	24	b
**Hieracium aurantiacum*			
**Hieracium praealtum*			
**Hypochaeris glabra*			
**Hypochaeris radicata*	26.5	81	
**Lactuca serriola*			
Lagenophora montana			a
Lagenophora stipitata[e]	3.3	33	b
Leptinella filicula	7.9	39	b
Leptorhynchos elongatus	0.7	4	b
Leptorhynchos squamatus subsp. *alpinus*	23.9	52	a
**Leucanthemum maximum*			
**Leucanthemum vulgare*	0.3	4	
Leucochrysum albicans subsp. *alpinum*	5.3	28	a
Leucochrysum albicans var. *albicans*	0.1	2	b
Leucochrysum albicans var. *buffaloensis*			a
Microseris sp. 2 (*sensu* Ross & Walsh 2003)	33.1	70	a
Olearia algida	9.1	39	a[1]
Olearia brevipedunculata	7.3	33	a
Olearia erubescens	0.4	6	c
Olearia floribunda	0.2	2	c
Olearia frostii	5.6	17	a
Olearia megalophylla	0.2	2	c
Olearia myrsinoides	0.2	4	b
Olearia phlogopappa var. *flavescens*	6.7	35	a
Olearia ramulosa var. *stricta*	0.2	6	c
Olearia rhizomatica			a
Ozothamnus alpinus	1.8	15	a
Ozothamnus sp. 1 (*sensu* Ross & Walsh 2003)	5.4	44	a
Ozothamnus rogersianus			b
Ozothamnus secundiflorus	2.5	19	b
Ozothamnus stirlingii			c
Ozothamnus thyrsoides			c
Parantennaria uniceps	0.8	4	a
Picris angustifolia subsp. *merxmuelleri*	1.2	13	b
Picris aff. *angustifolia* (Nungar Plain)	0.1	2	a
Podolepis lieracioides	0.5	7	b
Podolepis jaceoides	3.2	11	b
Podolepis robusta	5.5	41	a
Podolepis sp. aff. *robusta* (*sensu* Ross & Walsh 2003)	0.7	7	a
Rhodanthe anthemoides	5.3	30	b
Rutidosis leiolepis	0.9	6	b
Senecio extensus	0.7	9	a[1]
Senecio glabrescens			c
Senecio gunnii	8.2	57	b
Senecio lageniformis	0.4	4	a
Senecio linearifolius	0.7	11	c
Senecio longipilus	0.8	7	b
Senecio pectinatus var. *major*	3.3	31	a
Senecio pinnatifolius var. *alpinus*	19.4	67	a[1]
Senecio velleioides			c
Solenogyne dominii	0.4	4	c
Solenogyne gunnii	1.1	15	b
**Sonchus asper*			
**Sonchus oleraceus*			
**Tanacetum parthenium*			
Taraxacum aristum	0.5	6	b
**Taraxacum officinale sens. lat.*	8.7	50	
**Tragopogon dubius*	0.7	7	

**Tragopogon porrifolius*			
Vittadinia cuneata	0.3	2	c
Xerochrysum palustre	0.2	4	b
Xerochrysum subundulatum	9.0	37	b
Xerochrysum aff. *viscosa* (Cave Creek)	0.4	2	a
Boraginaceae			
Cynoglossum suaveolens			c
**Echium vulgare*	0.2	2	
Myosotis australis	0.4	4	b
**Myosotis caespitosa*	1.0	4	
**Myosotis discolar*	0.3	7	
Myosotis sp. (*sensu* Costin et al. 2000)			a
Brassicaceae			
Barbarea grayi	0.1	2	a
**Barbarea verna*			
**Capsella bursa-pastoris*			
Cardamine astoniae	1.5	7	a[1]
Cardamine lilacina	10.5	56	b
Cardamine papillata	0.2	2	b
Cardamine paucijuga			c
Cardamine robusta	0.2	4	a
Drabastrum alpestre	0.9	9	b
**Erophila verna* subsp. *verna*	0.1	2	
**Hirschfeldia incana*			
**Lepidium campestre*			
**Rorippa palustris*			
Callitrichaceae			
Callitriche palustris	0.1	2	b
**Callitriche stagnalis*	0.1	2	
Campanulaceae			
Lobelia gelida	0.1	2	a
Lobelia pedunculata	2.5	24	b
Lobelia surrepens	3.9	30	a[1]
Wahlenbergia ceracea	4.7	31	b
Wahlenbergia densifolia	0.3	6	a
Wahlenbergia gloriosa	1.4	20	b
Wahlenbergia gracilis	0.2	4	c
Wahlenbergia graniticala			c
Wahlenbergia multicaulis	0.1	2	c
Wahlenbergia stricta	0.4	4	c
Caryophyllaceae			
**Arenaria leptoclados*			
**Arenaria serpyllifolia*	0.1	2	
**Cerastium glomeratum*	7.8	37	
**Cerastium vulgare*	7.4	43	
Colobanthus affinis	4.2	26	a[123]
Colobanthus curtisiae	0.1	2	a
Colobanthus nivicola	0.7	4	a
Colobanthus pulvinatus	0.7	4	a[1]
**Dianthus armeria*	0.1	2	
**Gypsophila tubulosa*			
**Moenchia erecta*			
Sagina namadgi			b
**Sagina procumbens*			
Scleranthus biflarus	29.6	70	b
Scleranthus brockiei			a[12]
Scleranthus diander	0.6	4	b
Scleranthus fascicularis	1.4	7	a
Scleranthus singuliflorus	6.4	30	a[3]
**Spergularia media*	0.1	2	
**Spergularia rubra*	0.1	2	
Stellaria angustifolia	2.9	11	b
Stellaria flaccida	0.1	2	c
Stellaria multiflora	2.2	24	b
Stellaria pungens	13.7	56	b
Chenopodiaceae			
**Chenopodium album*			
Chenopodium erosum			c
Clusiaceae			
Hypericum gramineum	0.7	7	b
Hypericum japonicum	11.6	37	b
**Hypericum perforatum*	0.2	4	
Convolvulaceae			
Convolvulus angustissimus subsp. *angustissimus*	0.3	2	c
Dichondra repens	3.0	17	b
Crassulaceae			
Crassula helmsii			c
Crassula peduncularis	0.2	4	b
Crassula sieberiana	2.0	13	b
**Sedum acre*	0.3	2	
Dilleniaceae			
Hibbertia obtusifolia			c
Hibbertia pedunculata	0.3	4	c
Hibertia serpyllifolia			c
Droseraceae			
Drosera arcturi	3.8	11	a[12]
Drosera peltata subsp. *auriculata*			c
Drosera peltata subsp. *peltata*	1.4	7	b
Ericaceae			
Acrotriche divaricata			c
Brachyloma daphnaides	0.2	2	c
Epacris breviflora	6.0	17	a
Epacris celata	1.3	11	a
Epacris glacialis	6.7	19	a
Epacris gunnii	14.8	61	b
Epacris microphylla var. *rhombifolia*			a
Epacris paludosa	15.4	26	b
Epacris petraphila	4.7	22	a[1]

Epacris robusta	0.2	2	c
Gaultheria appressa	0.1	2	b
Leucopogon attenuatus			c
Leucopogon fraseri	1.6	15	b
Leucopogon gelidus	0.6	9	b
Leucopogon hookeri [f]			a[1]
Leucopogon maccraei	0.6	7	b
Leucopogon microphyllus var. *pilibundus*			c
Leucopogon montanus [f]			a[1]
Leucopogon pilifer	0.5	4	c
Monotoca oreophila			b
Monotoca rotundifolia			c
Monotoca scoparia	0.1	2	c
Pentachondra pumila	5.0	22	a[12]
Richea continentis	16.1	31	a
Richea victoriana			b
Trochocarpa clarkei	1.6	11	a
Euphorbiaceae			
Bertya findlayi			b
Micrantheum hexandrum	1.1	7	b
Poranthera microphylla [g]	8.4	43	c
Poranthera oreophila [g]			a
Fabaceae			
Almaleea capitata	0.1	2	a
Bossiaea buxifolia	0.2	2	c
Bossiaea foliosa	6.1	39	b
Bossiaea obcordata			c
Bossiaea riparia	0.3	2	a
**Cytisus scoparius* subsp. *scoparius*			
Daviesia mimosoides subsp. *acris*	0.1	2	b
Daviesia ulicifolia	0.8	13	b
Desmodium varians			c
Dillwynia palustris	0.3	6	a
Dillwynia prostrata	0.7	6	a
Dillwynia sericea			c
Glycine clandestina			c
Gompholobium huegelii			c
Hovea asperifolia subsp. *asperifolia*			
Hovea montana	21.1	54	a[1]
Hovea pannosa			c
Hovea aff. *heterophylla* (Long Plain)	1.1	7	a
Indigofera australis			c
**Lotus angustissimus*			
**Lotus corniculatus*			
**Lotus uliginosus*			
**Melilotus albus*			
Mirbelia oxylobioides	0.1	2	c
Oxylobium ellipticum	4.3	33	b
Podolobium alpestre	6.7	35	b
Pultenaea capitellata			a
Pultenaea fasciculata	1.3	13	a[1]
Pultenaea muelleri var. *muelleri*	2.0	6	b
Pultenaea polifolia	1.1	7	b
Pultenaea subspicata	0.7	7	b
Pultenaea tenella	4.1	13	a
Sphaerolobium vimineum			c
Swainsona monticola	0.6	4	a
**Trifolium ambiguum*			
**Trifolium arvense*	0.1	2	
**Trifolium campestre*	0.2	4	
**Trifolium dubium*	1.4	13	
**Trifolium hybridum*			
**Trifolium pratense*			
**Trifolium repens*	14.9	41	
**Vicia sativa*			
Fagaceae			
Nothofagus cunninghamii	0.1	2	c
Gentianaceae			
**Centaurium erythraea*	0.1	2	
Gentianella bawbawensis [h]			a
Gentianella cunninghamii subsp. *cunninghamii*			a
Gentianella cunninghamii subsp. *major*			a
Gentianella muelleriana subsp. *alpestris* [h]	2.7	19	a
Gentianella muelleriana subsp. *muelleriana* [h]	3.1	24	a
Gentianella muelleriana subsp. *jingerensis*	0.1	2	a
Gentianella muelleriana subsp. *willisiana* [h]			a
Geraniaceae			
Geranium antrorsum	11.9	44	a
**Geranium molle*			
Geranium neglectum	0.2	2	c
Geranium obtusisepalum			a
Geranium potentilloides var. *abditum* [i]			a
Geranium potentilloides var. *potentilloides* [i]	4.0	43	b
Geranium retrorsum	0.1	2	c
Geranium sessiliflorum subsp. *brevicaule*	0.3	7	a[1]
Geranium solanderi	0.5	9	b
Geranium sp. 7 (*sensu* Ross & Walsh 2003)	0.2	4	a
Pelargonium australe	0.1	2	b
Pelargonium helmsii	0.1	2	a
Goodeniaceae			
Goodenia hederacea subsp. *alpestris*	4.9	31	a
Scaevola hookeri	1.0	11	b

Velleia montana	5.4	26	a[1]
Velleia paradoxa			b
Haloragaceae			
Gonocarpus humilis	0.2	4	c
Gonocarpus micranthus subsp. *micranthus*	14.7	33	b
Gonocarpus montanus	8.0	54	b
Gonocarpus tetragynus	0.1	2	c
Haloragis heterophylla	0.1	2	c
Myriophyllum alpinum	0.3	7	a
Myriophyllum pedunculatum subsp. *pedunculatum*	5.8	24	b
Myriophyllum variifolium	0.3	6	c
Lamiaceae			
Ajuga australis sens. lat.	13.0	44	b
Mentha laxiflora			c
**Mentha spicata*			
Prostanthera cuneata	7.0	43	a
Prostanthera lasianthos			c
Prostanthera phylicifolia			c
**Prunella vulgaris*	0.7	6	
**Salvia verbenaca*			
Scutellaria humilis			c
Westringia lucida	0.4	6	a
Westringia senifolia	0.6	4	a
Lauraceae			
Cassytha pubescens			c
Lentibulariaceae			
Utricularia dichotoma			c
Utricularia monanthos	2.0	11	a[12]
Linaceae			
Linum marginale	2.7	19	b
Loganiaceae			
Logania albiflora			c
Mitrasacme serpyllifolia	0.2	2	b
Schizacme montana var *montana*	0.6	9	a
Malaceae			
**Cotoneaster horizontalis*			
**Malus domestica*			
Malvaceae			
**Malva nicaeensis*			
Menyanthaceae			
Nymphoides montana			b
Mimosaceae			
Acacia alpina	1.2	11	a
Acacia dealbata subsp. *subalpina*			c
Acacia gunnii			c
Acacia melanoxylon			c
Acacia obliquinervia			c
Acacia siculiformis	1.0	6	c
Myrtaceae			
Baeckea gunniana	17.2	39	a[1]
Baeckea latifolia			a
Baeckea utilis	3.1	11	b
Callistemon pallidus			c
Callistemon pityoides	5.2	9	b
Calytrix tetragona		c	
Eucalyptus debeuzevillei	0.2	4	b
Eucalyptus kybeanensis			c
Eucalyptus lacrimans	0.4	2	b
Eucalyptus niphophila	0.6	11	b
Eucalyptus pauciflora			c
Eucalyptus stellulata	0.2	4	b
Euryomyrtus denticulata			c
Euryomyrtus ramosissima subsp. *ramosissima*	4.2	11	b
Kunzea ericoides sens. lat.			c
Kunzea muelleri	10.1	43	a
Kunzea parvifolia	0.2	2	c
Leptospermum brevipes			c
Leptospermum grandifolium	0.7	9	c
Leptospermum jingera			a
Leptospermum lanigerum			c
Leptospermum micromyrtus	0.1	2	b
Leptospermum myrtifolium	0.7	7	a
Leptospermum namadgiensis	0.2	2	a
Onagraceae			
Epilobium billardierianum subsp. *cinereum*	12.8	54	b
Epilobium billardierianum subsp. *hydrophilum*			b
Epilobium brunnescens subsp. *beaugleholei*			a
**Epilobium ciliatum*	0.2	4	
Epilobium curtisiae	2.0	11	a[1]
Epilobium gunnianum	9.9	39	b
Epilobium hirtigerum	0.3	2	c
Epilobium sarmentaceum	0.7	9	a[1]
Epilobium tasmanicum	1.1	11	a[12]
Epilobium willisii			a[1]
Oxalidaceae			
Oxalis exilis	2.2	17	b
Oxalis magellanica	0.4	4	b
Pittosporaceae			
Billardiera macrantha			c
Rhytidosporum alpinum	1.6	9	a[1]
Rhytidosporum inconspicuum			a
Rhytidosporum procumbens	0.9	9	c
Plantaginaceae			
Plantago alpestris	2.8	17	a
Plantago antarctica	4.0	26	a[1]
Plantago euryphylla	15.0	56	a
Plantago glacialis	1.1	6	a

Plantago hispida			c
**Plantago major*			
Plantago muelleri	1.3	6	a
Plantago varia	2.1	13	c
Polemoniaceae			
**Collomia grandiflora*			
**Navarettia squarrosa*			
Polygalaceae			
Comesperma ericinum			c
Comesperma retusum	2.0	4	b
Comesperma volubile			c
Polygala japonica			c
Polygonaceae			
**Acetosella vulgaris*	42.9	83	
**Fallopia japonica*			
Muehlenbeckia axillaris	0.2	4	a[12]
**Polygonum arenastrum*			
**Polygonum aviculare*			
Rumex brownii	0.2	6	b
**Rumex conglomeratus*	0.1	2	
**Rumex crispus*			
**Rumex obtusifolius*			
Portulacaceae			
Montia fontana subsp. *amporitana*			a
Montia fontana subsp. *fontana*	0.3	2	a
Neopaxia australasica	4.7	33	b
Primulaceae			
**Anagallis arvensis*			
Proteaceae			
Banksia marginata			c
Grevillea australis	26.6	67	a[1]
Grevillea diminuta			a
Grevillea lanigera	0.7	9	b
Grevillea victoriae subsp. *nivalis*			b
Grevillea victoriae subsp. *victoriae*	0.2	6	a
Hakea lissosperma	0.1	2	a
Hakea microcarpa	8.7	33	b
Orites lancifolia	7.3	28	a
Persoonia chamaepeuce	0.7	11	b
Persoonia subvelutina			c
Ranunculaceae			
**Aquilegia vulgaris*			
Caltha introloba	5.6	19	a
Clematis microphylla var *leptophylla*	0.2	2	c
Ranunculus acrophilus	0.5	4	a
Ranunculus amphitrichus	0.9	9	b
Ranunculus anemoneus	1.9	17	a
Ranunculus clivicola	0.2	2	a
Ranunculus collinus	3.0	11	a[1]
Ranunculus diminutus	0.1	2	b
Ranunculus dissectifolius	0.7	9	a
Ranunculus eichlerianus	3.2	19	a
Ranunculus graniticola	21.8	56	a
Ranunculus gunnianus	5.6	33	a[1]
Ranunculus lappaceus	1.3	7	b
Ranunculus millanii	2.4	17	a
Ranunculus muelleri	2.8	26	a
**Ranunculus muricatus*	0.1	2	
Ranunculus niphophilus	0.7	7	a
Ranunculus papulentus			c
Ranunculus pimpinellifolius	7.4	13	a[1]
Ranunculus pumilio var. *pumilio*			c
**Ranunculus repens*			
Ranunculus scapiger			c
Ranunculus victoriensis	9.3	22	a
Rhamnaceae			
Cryptandra amara	0.3	4	c
Discaria nitida			a
Discaria pubescens	0.1	2	b
Rosaceae			
Acaena agnipila	0.2	2	c
Acaena echinata	2.7	19	b
Acaena novae-zelandiae			c
Acaena ovina	1.6	13	b
Acaena sp. (*sensu* Costin et al. 2000)	20.4	74	a
Alchemilla sp. 1 (*sensu* Ross & Walsh)	0.1	6	a
**Aphanes arvensis*	2.4	11	
Aphanes australiana	0.2	2	c
**Aphanes inexpectata*			
**Crataegus monogyna*			
Geum urbanum var. *strictum*	0.4	6	a
**Potentilla recta*	0.1	2	
**Rosa rubiginosa*	0.3	2	
**Rubus anglocandicans*			
**Rubus leucostachys*			
Rubus parvifolius	0.4	7	b
Rubiaceae			
Asperula conferta	0.6	11	b
Asperula euryphylla	0.2	2	c
Asperula gunnii	53.0	81	b
Asperula pusilla	3.0	28	a[1]
Asperula scoparia	2.4	17	b
Coprosma hirtella	0.2	6	c
Coprosma moorei	0.7	6	a[1]
Coprosma niphophila	0.6	4	a[2]
Coprosma nitida	0.7	9	a[1]
Coprosma nivalis	1.2	15	a
Coprosma perpusilla subsp. *perpusilla*	0.6	2	a[1]

Coprosma pumila			a[12]
Galium ciliare			c
Galium gaudichaudii	0.5	6	c
Galium migrans			c
Galium propinquum			c
Galium roddii	0.4	4	a
Nertera sp. (*sensu* Costin et al. 2000)	5.3	17	a
Rutaceae			
Asterolasia trymalioides	9.6	35	a
Boronia algida	0.2	4	b
Crowea exalata subsp. *exalata*	0.7	6	c
Leionema phylicifolium	2.0	20	c
Leionema lamprophyllum			c
Nematolepis ovatifolia	3.6	19	a
Nematolepis squamulosa subsp. *alpinum*	6.7	33	a
Nematolepis squamulosa subsp. *ozothamnoides*	0.2	4	c
Salicaceae			
**Salix cinerea*	0.1	2	
**Salix* x *rubens*	0.1	2	
Santalaceae			
Choretrum pauciflorum			c
Exocarpus cupressiformis			c
Exocarpus nanus	3.2	26	b
Thesium australe			b
Sapindaceae			
Dodonaea viscosa			c
Scrophulariaceae			
Chionohebe densifolia	0.4	4	a[2]
Derwentia derwentiana subsp. *derwentiana*	0.4	9	a
Derwentia derwentiana subsp. *maideniana*			a
Derwentia nivea	0.1	2	a
Derwentia perfoliata	0.6	9	b
Euphrasia alsa	0.1	2	a
Euphrasia caudata	0.6	4	a
Euphrasia collina subsp. *diversicolor*	5.8	31	a
Euphrasia collina subsp. *glacialis*	0.7	7	a
Euphrasia collina subsp. *lapidosa*	0.4	4	a
Euphrasia collina subsp. *paludosa*	8.5	44	b
Euphrasia collina subsp. 1 (*sensu* Ross & Wlash 2000)			a
Euphrasia crassiuscula subsp. *crassiuscula*	1.6	9	a
Euphrasia crassiuscula subsp. *eglandulosa*			a
Euphrasia crassiuscula subsp. *glandulifera*			a
Euphrasia eichleri			a
Euphrasia gibbsiae subsp. *subglabrifolia*	2.3	4	a
Euphrasia lasianthera			a
Euphrasia scabra sens. lat.			c
Euphrasia sp. 3 (Ramshead Range *sensu* Briggs & Leigh 1996)			a
Glossostigma cleistanthum			c
Gratiola nana	0.6	9	a[1]
Limosella australis	0.2	4	b
**Linaria arvensis*	0.2	2	
**Mimulus moschatus*	0.6	6	
**Parentucellia latifolia*			
**Verbascum thapsus*	0.2	4	
**Verbascum virgatum*	0.1	2	
**Veronica arvensis*	0.8	11	
Veronica calycina			c
Veronica gracilis	1.9	17	b
Veronica serpyllifolia sens. lat.	2.8	19	b
Stackhousiaceae			
Stackhousia monogyna	0.4	9	b
Stackhousia pulvinaris	4.7	28	a[1]
Stackhousia viminea			c
Stylidiaceae			
Stylidium armeria[3]			
Stylidium montanum[3]	16.3	69	a
Thymelaeaceae			
Kelleria dieffenbachii	0.6	6	a[12]
Kelleria laxa			a[2]
Pimelea alpina	23.4	56	a
Pimelea axiflora subsp. *alpina*	9.2	35	a
Pimelea biflora	3.3	22	a
Pimelea bracteata	1.0	4	a
Pimelea linifolia subsp. *caesia*	5.6	22	a
Pimelea ligustrina subsp. *ciliata*	2.3	15	a
Pimelea microcephala	0.2	4	
Pimelea pauciflora	0.3	4	b
Tremandraceae			
Tetratheca bauerifolia	0.2	4	c
Tetratheca procumbens			a
Urticaceae			
Urtica incisa			c
**Urtica urens*			

Violaceae			
Melicytus sp. aff. *dentatus* (Snowfields variant *sensu* Ross & Walsh 2000)	15.4	63	a
**Viola arvensis*	0.3	4	
Viola betonicifolia subsp. *betonicifolia*	28.2	70	b
Viola fuscoviolacea	2.9	17	a
Viola hederacea	2.9	15	b
Viola improcera	0.2	2	a
**Viola odorata*			
Winteraceae			
Tasmannia lanceolata			c
Tasmannia xerophila subsp. *xerophila*	2.9	20	b
Tasmannia vickeriana	1.1	6	a

[a] The frequencies of these *Prasophyllum* spp. are probably underestimated. Unidentified *Prasophyllum* species occurred in 11% of quadrats and 76% of communities.

[b] These species were recorded in early surveys as *Agrostis hiemalis* (in 3% of quadrats and 15% of communities).

[c] The frequencies of these *Celmisia* spp. are probably underestimated. Unidentified *Celmisia* species occurred in 32% of quadrats and 48% of communities. The name *Celmisia pulchella* has been suggested for a diminutive species known from wet heathland communities in Kosciuszko National Park, wetlands along the NSW coastal escarpment and Central Tablelands.

[d] The frequencies of these *Craspedia* spp. are probably underestimated. Unidentified *Craspedia* species occurred in 29% of quadrats and 63% of communities.

[e] Some records of *Lagenophora stipitata* are probably referable to *L. montana*, which was not widely recognised at the time of the earlier surveys.

[f] The frequencies of these *Leucopogon* spp. are probably underestimated; *L. hookeri* and *L. montanus* were grouped in the survey of McDougall (1982) because of difficulties with identification when not in flower.

[g] Most records of *Poranthera microphylla* are probably referable to *P. oreophila*, a recently described species.

[h] The frequencies of these *Gentianella* spp. are probably underestimated. Unidentified *Gentianella* species occurred in 8% of quadrats and 26% of communities.

[i] No distinction was made between the varieties of *Geranium potentilloides* in the early surveys. The data shown for var. *potentilloides* will contain some records of var. *abditum*.

[j] The data shown for *Stylidium montanum* will contain some records of *S. armeria* (especially on the Bogong High Plains where *S. armeria* is the more common species in shrublands), both of which were included in *S. graminifolium* at the time of the early surveys.

Floristic variation in *Sphagnum*-dominated peatland communities of the Central Highlands, Victoria

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Abstract: The floristic composition of *Sphagnum*-dominated peatlands in the Central Highlands region of Victoria was surveyed (37° 25´ S; 145° 50´ E). NMDS ordination and cluster analysis divided the peatland sites into two broad groups with altitude being the most important factor separating these groups. Other important factors were aspect, slope and the amount of shade. Group 1 included subalpine sites that are similar to those found at higher altitudes further east in Victoria. Important species included *Empodisma minus*, *Epacris paludosa*, *Richea continentis* and *Baeckea gunniana*. The two species of *Sphagnum* present were *Sphagnum cristatum* and the more inundation-tolerant *Sphagnum novo-zelandicum*. Group 2 included montane peatlands with abundant *Sphagnum cristatum*. These sites range from broad wet heaths dominated by *Richea victoriana* and *Carex appressa*, to narrower cool temperate rainforest and riparian systems. The 'rainforest' peatlands are characterised by *Leptospermum grandifolium*, *Nothofagus cunninghamii*, *Carex appressa* and *Blechnum penna-marina*, and are in varying stages of post-fire succession regulated by site-specific microclimate. The conservation status and catchment function of these peatlands are briefly discussed.

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Introduction

Sphagnum mires and peatlands are most prominent at higher latitudes and altitudes. Watertables constantly at, or near the soil surface, are required for peatlands to develop and persist. The resultant anoxic, low nutrient, acidic soil conditions can only be tolerated by bryophytes and specially adapted vascular plants. These soil conditions impede decomposition and nutrient cycling, allowing organic matter accumulation to exceed decay and the excess to be deposited as peat. The vegetation in *Sphagnum*-dominated peatlands is typically a mix of sedges, rushes and low xeromorphic shrubs protruding from an almost continuous, undulating mat of *Sphagnum* moss. Herbs, lilies and other geophytes are also common (Gore 1983a, Charman 2002, Joosten & Clarke 2002).In Australia, these ecosystems are understandably restricted in distribution, accounting for less than 0.02% of the continent (Joosten & Clarke 2002) and are most extensive in western Tasmania and elevated areas of the south-eastern states (Gore 1983b). There have been numerous studies of peatlands throughout their range in Australia, with most of the scientific research focussed on the alpine areas of Tasmania, southern New South Wales and north-east Victoria. These have described floristic composition, system dynamics, anthropogenic impacts and hydrological importance (Costin 1954, Wimbush & Costin 1979, McDougall 1982, Kirkpatrick 1983, Clarke & Martin 1999, Wahren et al. 1999; Wahren et al. 2001, Whinam et al. 2001).

Sphagnum peatland systems occurring in subalpine and montane areas elsewhere have received less scrutiny. In Victoria, *Sphagnum* systems have been incorporated in studies of subalpine vegetation at the Bennison Plains (Farrell & Ashton 1973), Lake Mountain (Ashton & Hargreaves 1983), Mount Buffalo (Wahren & Walsh 2000), the Snowy Range (Wahren & Papst 1999) and on the Baw Baw plateau (Walsh et al. 1986).

Montane and subalpine peatland systems near Lake Mountain in the Central Highlands of Victoria (37° 25´ S; 145° 50´ E) were included in a recent state-wide survey by Whinam et al. (2003), but there are other montane peatlands similar to these elsewhere in the region, including largely undocumented subalpine *Sphagnum* mires at Mount Bullfight and Mount Torbreck on the nearby Federation Range (Willis 1948). In this paper, the floristic character of *Sphagnum*-dominated plant communities in the Central Highlands region is examined and possible factors responsible for observed differences amongst sites investigated. The broad aims were to:

1) Document and characterise the floristic composition and structure of *Sphagnum* peatlands and associated communities in the Central Highlands and compare them with similar communities elsewhere in Victoria and southern New South Wales.

2) Determine the degree of variability apparent amongst the peatland communities in terms of floristic composition, structure and landscape setting, and investigate possible environmental factors responsible for observed differences.

Methods

Study region

The study area is an elevated plateau (> 900 m) and associated ranges extending north from the Great Dividing Range near Marysville, 120 km north-east of Melbourne (Fig.1). The area (approximately 400 km²) is bounded in the north by the Goulburn River valley, in the west by the Acheron valley, and on the eastern side by the Big River basin. The western part of this land system is sometimes referred to as the Blue Range or Cerberean Ranges, the eastern as the Federation Range. Highest elevations are along the eastern flank, and range from 1514 m in the north-east at Mount Torbreck, to approximately 1450 m further south at Lake Mountain. All the streams and rivers that drain the study area ultimately feed into the Goulburn River system; the eastern streams via Big River and Lake Eildon, and the western streams via the Acheron and Rubicon Rivers. Wet heathlands and closed riparian scrubs containing *Sphagnum* associated plant communities and mires are located in the headwater streams of these rivers (LCC 1973, Rundle 1977).

The geology of the Central Highlands is relatively uniform, with an upper Devonian dacite-rhyodacite igneous complex extending from Mount Torbreck in the north-east to Mount Donna Buang at the south-western end (Rundle 1977, Ashton & Hargreaves 1983, McKenzie 1997). There are smaller areas of granite outcrop of similar age. The topography is moderate to gently sloping and the major stream systems are generally parallel and follow joint systems and fractures in the igneous bedrock (LCC 1973).

The broader scale vegetation patterns of the region reflect a steep rainfall gradient with movement from the lowlands of the Acheron and Goulburn valleys to the crest of the Cerberean plateau (LCC 1973, Rundle 1977). The northern and western fringes below 600 m carry a dry foothill forest, which becomes damp sclerophyll forest on steeper more elevated ridges. Wet sclerophyll forests dominate most of the plateau with stands of Alpine ash (*Eucalyptus delegatensis*), Shining gum (*Eucalyptus nitens*) and Mountain ash (*Eucalyptus regnans*). Cool temperate rainforest consisting of *Nothofagus cunninghamii* and *Atherosperma moschatum* can be found along stream-lines and gullies, above approximately 600 m. Woodlands of *Eucalyptus pauciflora* occur at altitudes above 1340 m (LCC 1973).

Climate

There is a southern or maritime influence on the climate and precipitation occurs mostly from April to October, peaking in July and August. The mean annual rainfall for Rubicon, in the north of the study area (37° 19' 35" S; 145° 51' 40" E; 380 m.), is 1698 mm (Bureau of Meteorology, Melbourne). BIOCLIM precipitation estimations for several locations on the plateau proper suggest annual averages in excess of 1600 mm are likely over most of the area (McKenzie 1997). Even in the driest period of the year (Jan–Mar), mean monthly precipitation totals on the plateau are likely to be little below 100 mm.

Snowfalls are frequent from May to September, although below 1200 m, snow rarely accumulates to a depth of more than 30 cm. During this period, the mean duration of snow cover above 1200 m is one month, increasing to 10–12 weeks at 1400 m, especially in more sheltered pockets and aspects. Frosts are common in the cold-air drainage hollows of the plateau and largely responsible for inverted tree-lines similar to those present in montane and subalpine areas throughout south-east Australia (Williams 1987, Williams and Costin, 1994). BIOCLIM estimations of mean annual temperatures for several locations (900–1400 m) range between 6.5°C and 10.4°C (McKenzie 1997)

Land use history and current tenure

There has been forestry activity in the area since the late 19th century, and more intensive since the late 1960s. A small hydro-electricity scheme was constructed by the SEC in the Rubicon area during the 1920s and is still in operation (AHC & CNR 1994b). The Lake Mountain-Echo Flat area was subject to livestock grazing until the mid-1960s, although stock numbers were reputedly never large (Ashton & Hargreaves 1983). Low intensity forest grazing also occurred until the 1930s. In recent decades, parts of the study area have become important for recreation purposes, particularly cross-country skiing, bushwalking, deer-stalking and four-wheel drive touring.

The southern parts of the study area are included in the Yarra Ranges National Park, but most is State Forest (Rubicon or Marysville). The Mount Bullfight and Mount Torbreck peatlands are in scenic features or nature conservation reserves (AHC & CNR 1994a).

Floristic sampling

A total of 20 sites were sampled across the region (Fig. 1) using the information obtained from previous studies as a starting point (Ashton & Hargreaves 1983, Walsh et al. 1986, McKenzie 1997). By coupling a knowledge of the landscape setting of known sites with an examination of the relevant 1:100 000 and 1:25 000 topographic map sheets, it was possible to determine a series of other likely *Sphagnum* peatland locations. These were verified during February and March 2003. Some proved to be *Sphagnum* peatlands, others not, but in the process of ground exploration, other sites, less obvious from map examination, were located.

The 20 *Sphagnum* sites surveyed were given a nominal classification according to altitude, landscape position and surrounding forest vegetation type (Table 1). The seven higher altitude subalpine sites (>1300 m) were typically bounded by *Eucalyptus pauciflora* open forest with an

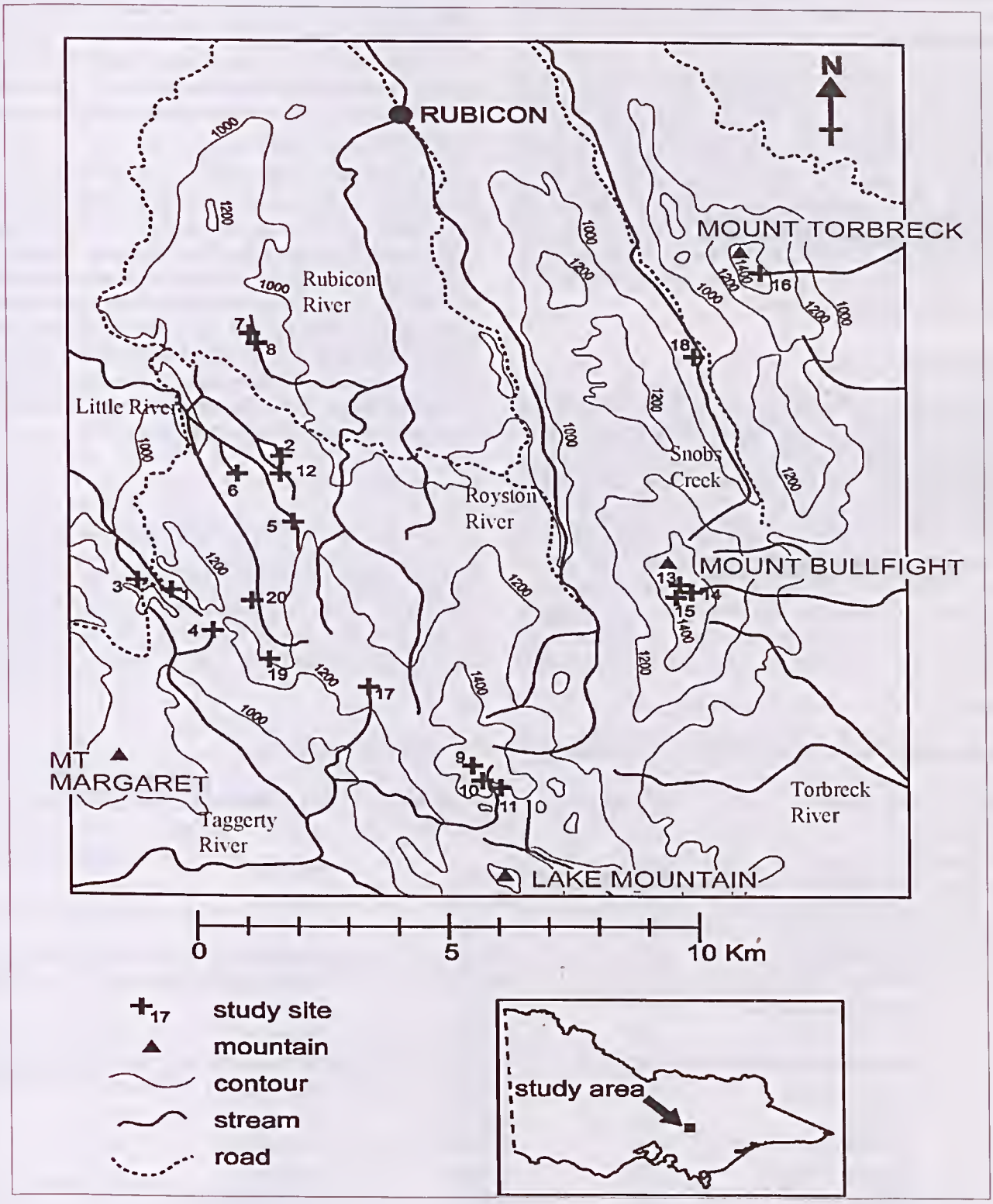


Fig. 1. The Central Highlands region of Vietoria showing the loeation of the 20 *Sphagnum* peatland study sites. (See Table 1 for site names)

understorey of heathy shrubs, whereas the 13 nominally montane sites (900–1300 m) were surrounded by tall open forest (wet sclerophyll) and cool temperate rainforest containing *Nothofagus cunninghamii*.

At each site, floristic composition and abundance were recorded in a 10 x 10 m quadrat. Site selection criteria required a minimum 30% *Sphagnum* cover, as used by Whinam et al. (2003). All vascular plant taxa were identified and their percent cover was recorded using the Braun-Blanquet cover abundance scale. *Sphagnum* species and *Polytrichum commune* (> 5% cover at some sites) were the only bryophytes identified, although other bryophytes were present in very low abundances. Species nomenclature follows Ross and Walsh (2003).

Environmental factors

In each quadrat, peat and substratum depth were recorded using a 1.2 m stainless steel probe. Ten randomly located measurements were recorded across the quadrat and an average calculated. Where peat depths exceeded the probe length, depth was recorded as >1.2 m. Three peat or soil samples were collected from each plot and later tested in the laboratory for pH using the 1:5 distilled water solution method (Rayment & Higginson 1992). The proportion of bare ground and litter were also estimated using the Braun-Blanquet scale, as was the amount of free-water cover within the quadrat. The available light or amount of shade at ground level was ranked from full light (class 0) to full shade and 100% canopy cover (class 5). The average height of the canopy strata was estimated in each quadrat. Where shrubs represented the upper layer, estimation was to the nearest 0.3 m. When tall shrubs or small trees comprised the canopy layer, estimations were to the nearest metre. The combined percent cover of all *Sphagnum* species within each quadrat was also used as a variable.

Aspect was determined using a hand held 'Suunto' bushwalking compass and later assigned to one of five categories: (1) north-west aspect, (2) north or west aspect, (3) north-east or south-west, (4) south or east, (5) south-east. This system of classification reflects the gradient in moisture loss due to evaporation in the mid-latitudes of the southern hemisphere, from high (1) to low (5) (Kirkpatrick & Bridle 1998). Slope was estimated subjectively and allocated to one of three categories: (0) flat or barely perceptible, (1) slight but definite slope (<5%), (2) more pronounced slope (<10%). In all cases the slope was less than 10%.

Data analyses

The data consisted of 20 sites in which 85 plant species were recorded. Single species occurrences, of which there were 24, were deleted for the purposes of analysis. The amount of *Sphagnum* cover was examined as a factor influencing composition; thus, it was appropriate to remove the two *Sphagnum* species recorded from the analysis data matrix.

Table 1. Locality details of the 20 *Sphagnum* peatlands surveyed in the Central Highlands region.

Site No.	Site Name	Altitude (m)	Surrounding Forest Type	Land Tenure	Size (ha)
1	Storm Creek	1175	Montane	State forest	4.0
2	'Carex Bog'	1090	Montane	State forest	1.2
3	Storm Creek West	1180	Montane	State forest	0.4
4	Whitehouse Creek	1180	Montane	State forest	0.2
5	McFadyens Track No.1	1135	Montane	State forest	1.0
6	McFadyens Track No.2	1085	Montane	State forest	1.0
7	Tom Burns Creek No.1	1090	Montane	State forest	3.0
8	Tom Burns Creek No.2	1090	Montane	State forest	3.0
9	Triangle Junction	1430	Subalpine	National Park	2.0
10	Long Flat	1400	Subalpine	National Park	4.0
11	'The Camp'	1390	Subalpine	National Park	0.6
12	McFadyens Track No.3	1100	Montane	State forest	0.2
13	Bullfight No.1	1420	Subalpine	Conservation Reserve	0.5
14	Bullfight No.2	1405	Subalpine	Conservation Reserve	1.2
15	Bullfight No.3	1420	Subalpine	Conservation Reserve	0.4
16	Torbreck	1430	Subalpine	Scenic Reserve	0.6
17	Keppel Hut	1290	Montane	State forest	0.2
18	Snobs Creek	910	Montane	State forest	0.2
19	Boundary Trail	1190	Montane	State forest	0.8
20	Little River	1115	Montane	State forest	0.8

This left a final count of 59 species. Cover-abundance classes were converted to their mid-point percent values. Separate analyses were run using both percent cover data and species presence-absence data. The former of these methods emphasises dominant species, whereas the latter, similarity in overall composition. Presence-absence data may exaggerate the importance of infrequently occurring species.

The data were analysed using non-metric multi-dimensional scaling (NMDS) techniques (Minchin 1987). Classification and cluster analysis (Group-average-linkage) were used subsequently to confirm apparent groupings in the ordination and identify possible sub-groupings. Ordinations were performed in two and three dimensions on both cover-abundance and presence /absence data, using 30 random starting configurations with 1000 iterations for each. The Bray-Curtis coefficient was used to measure dissimilarity for both ordinations and cluster analysis (Faith et al. 1987). Minimum stress configurations were compared using procrustean analysis. Stress is a measure of the goodness of fit and levels below 0.2 are acceptable and biologically meaningful (Clarke 1993). The two dimensional solutions are easier to interpret and were preferred for analysis, unless stress values were greater than 0.2.

Vectors of maximum correlation with the ordinations were fitted for all the variables outlined in the environmental factors section. The significance level of these was tested using Monte-Carlo procedures which compares the observed maximum correlation with the distribution of values using 1000 permutations (P = 0.001). Only the trend directions of those significantly correlated with the sample ordination and responsible for greater than 50% of the variability (R^2>0.5) were superimposed on the resultant configuration to assist interpretation (Minchin 1987). The presentation of ordinations and vector diagrams follow a format similar to that used in Wahren (1997).

Key discriminating species

The species characteristic of groups within the vegetation samples and those distinguishing groups were determined using the SIMPER procedure (Clarke 1993), which uses similarity and dissimilarity measures to determine the species that best define vegetation units and those that most effectively discriminate between them. The contribution of each species to the similarity (Si) or dissimilarity (Di) can then be assessed and there are two indicators that measure the consistency of this contribution. These are the standard deviation of the mean similarity (SD(Si)), and the ratio of the mean to the standard deviation (Si/SD(Si)). The most useful indicator species will have a low standard deviation value and hence, a high ratio value. Important species in one floristic group are not necessarily useful discriminators between units.

Software

Ordination and vector fitting procedures in this study employed the Database for Ecological Data Analysis (DECODA) program (Minchin 1989). Resulting configuration coordinates and vector line angles were plotted using SYSTAT (version 10.0). Cluster analysis and SIMPER procedures were performed using the Plymouth Routines in Multivariate Ecological Research software package (PRIMER, version 4.0, 1997).

Results

Summary of the flora

Of the 85 species recorded, 79 (93%) were native and six exotic. Several Victorian endemics were recorded: *Carex alsophila*, *Epacris microphylla* var. *rhombifolia*, *Wittsteinia vacciniacea* and *Richea victoriana*. These last two are locally abundant but elsewhere only occur in the vicinity of the Baw Baw plateau. *Coprosma moorei* and *Brachyscome obovata* are listed as rare in Victoria and, in this study, were recorded at Mount Bullfight and Lake Mountain respectively. *Sphagnum cristatum* was present at all sites surveyed. Several of the higher altitude sites also contained *Sphagnum novo-zelandicum*, which is more inundation-tolerant and typically occurs in shallow hollows and pools.

Table 2. Environmental variables showing high correlation with NMDS ordination configurations. P-values are: * = significant at 0.05 level; ** = 0.01 ; * = 0.001.**

	Cover (%) Data		Presence- Absence Data	
Environmental Variable	**Maximum correlation (R^2-value)**	**Significance (P-value)**	**Maximum correlation (R^2-value)**	**Significance (P-value)**
Altitude	0.848	0.001**	0.867	0.000***
Canopy	0.710	0.003**	0.820	0.000***
Shade	0.578	0.024*	0.725	0.000***
Aspect	0.594	0.026*	0.540	0.054
Slope	0.830	0.001**	0.614	0.003**
Water	<0.5	NS	0.529	0.075

Of the 82 vascular taxa identified, there were 32 forbs or creepers, 21 grasses or sedges, 16 small or medium shrubs, 3 tall shrub or small tree species, 6 lilies and orchids, and 4 ferns. Only 6% of species occurred at more than 12 sites, while 85% were present at eight sites or less. Five of the six exotic species recorded were only found at two sites or less, the exception being the cosmopolitan *Hypochoeris radicata* which was recorded at four sites. Two other introduced species were observed in the wet heathlands surveyed but were not recorded within the 100 m² plots. Several mature individuals of *Salix cinerea* were located at three of the montane sites, while the two small patches of *Lotus corniculata* were both observed at Storm Creek.

NMDS ordinations and fitted environmental vectors of significant correlation.

Minimum stress configurations in two dimensions for the NMDS ordinations based on percent cover data clearly separate the twenty sites into two groups (Fig. 2). The seven subalpine sites and one of the nominally montane sites (Storm Creek) form a cluster on the right of the ordination space. This group is henceforth referred to in the text as the 'subalpine' group for ease of description. The remaining montane sites form a less tightly clustered group on the left. Greater separation amongst the montane sites suggests more floristic variation across this group.

Five of the 10 environmental variables tested for correlation with the percent cover ordination configuration were significant ($P < 0.05$, Table 2). These were altitude, slope, aspect, shade and canopy height. The fitted vector for altitude is unsurprisingly orientated towards the cluster of subalpine sites (Fig. 2). The other four fitted vectors are somewhat diagonal to the two axes although more aligned with the vertical axis. The vectors for slope and aspect are correlated slightly with the subalpine cluster, but more importantly, are directed in the opposite direction to shade and canopy height. The latter factors all increase in value towards montane sites.

The minimum stress ordination configuration based on the presence /absence data, while again clearly separating subalpine and montane groups, suggests a looser association amongst the subalpine group than was apparent in the ordination derived from the percent cover data (Fig. 3). There is considerable spread in both groups along the vertical axis. Only four of the 10 tested environmental variables were significant (Table 2): altitude, canopy height, slope and shade. Aspect and water cover were marginally significant and still recorded 'R^2' correlation values of greater than 0.5 (50% of the variation attributable to the variable in question). Their vector lines are arguably of some interpretative value and have been plotted.

Canopy height and shade are correlated, to a certain extent, with the vertical axis and no doubt explain much of the variation amongst the montane group. They are slightly orientated towards these sites. The vector for water cover points in the opposite direction to shade and canopy height, while the vector for aspect runs diagonal to the main axes, but is directed more towards the subalpine group.

Key species representing the two groups.

Vascular plant species identified by SIMPER analysis as being significant indicator species and important contributors to similarity amongst subalpine *Sphagnum* peatlands were *Empodisma minus* and the shrubs *Baeckea gunniana*, *Epacris paludosa* and *Richea continentis* (Table 3b). These species also feature at the higher end of the altitude vector divide (Table 5a). Conversely, species that were more abundant at the lower end of the altitude vector divide were important contributors to the similarity amongst montane sites (Tables 3a & 5a). Amongst these were *Leptospermum grandifolium*, *Carex appressa*, *Richea victoriana* and *Blechnum penna-marina*. Many of the species comprising these two sets were also identified as useful discriminators of the montane and subalpine sites (Table 4). Most notable amongst these was *Empodisma minus* which had an average cover of 32% in the subalpine peatlands, but was entirely absent from sites in the montane group. *Baeckea gunniana* was also restricted to the subalpine group. On the other hand, *Leptospermum grandifolium* averaged 24% cover in montane sites, but was a very minor component in subalpine peatlands (0.06% cover). The two heath species from the genus *Richea* are of interest in this regard; *Richea victoriana* being mostly confined to montane sites and *Richea continentis* to subalpine. In montane areas, the only recording of *Richea continentis* was at the Boundary Trail site (1190 m), which is less than five kilometres from the extensive Lake Mountain subalpine wet heathlands.

Taxa more prevalent in shaded sites were those typical of montane cool temperate rainforest and riparian vegetation. These included the canopy species *Nothofagus cunninghamii* and *Leptospermum grandifolium* as well as ground stratum plants such as *Blechnum penna-marina*, *Libertia pulchella* and *Wittsteinia vacciniacea*. Subalpine species such as *Baeckea gunniana*, *Epacris paludosa*, *Empodisma minus*, *Juncus sandwithii* and *Oreobolis oxycarpus* feature in high light conditions at the opposite end of the shade vector (Table 5b), reflecting the generally more open nature of the subalpine systems.

Subgroups within montane and subalpine Sphagnum peatlands

Cluster analysis of the presence /absence data using group-average-linkage and the Bray-Curtis similarity coefficient separates the peatland sites into montane and subalpine clusters at the 20% similarity level (Fig. 4). The montane group can be generally separated into two subgroups using the presence /absence ordination configuration and associated vectors (Fig. 3). Sites 2, 5, 6 and 20 form a cluster at 60%

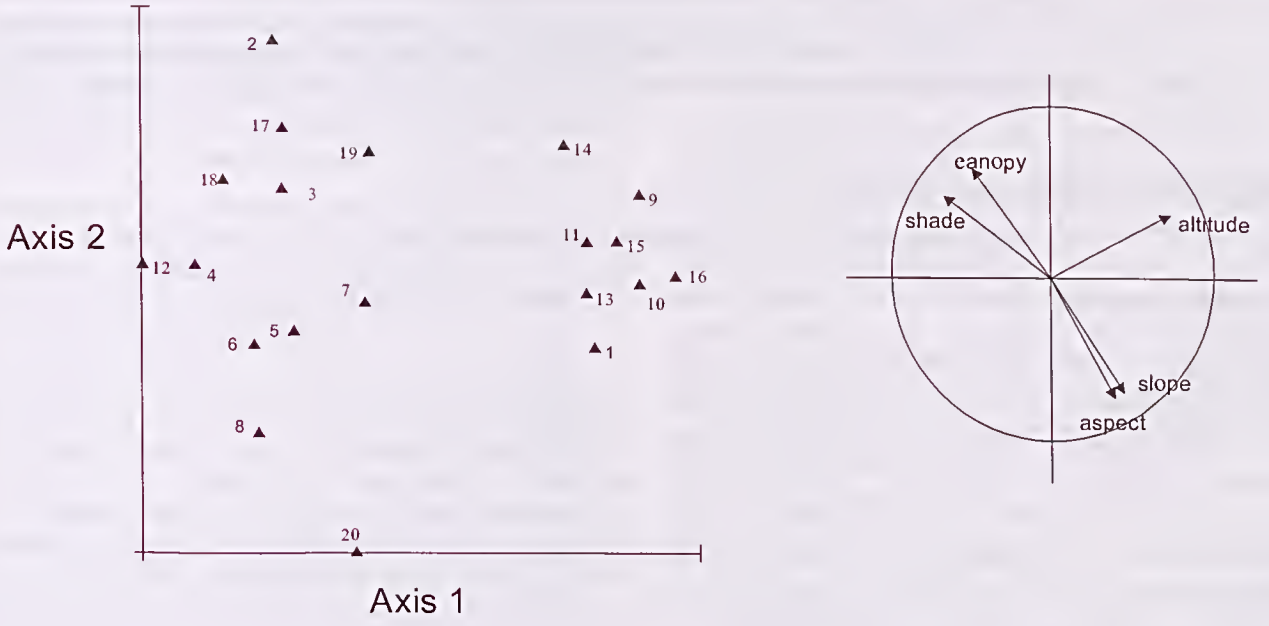


Fig. 2. NMDS ordination of the Central Highlands *Sphagnum* peatland sites. Two dimensional configuration based on (%) cover data, with the vector diagram for factors significantly correlated with the configuration (Minimum stress = 0.11).



Fig. 3. NMDS ordination of the central highlands *Sphagnum* peatland sites. Two dimensional configuration based on presence /absence data, with the vector diagram for environmental factors significantly correlated with the configuration (Minimum stress = 0.10).

Table 3. Mean cover (%) of important species in the Central Highlands *Sphagnum* peatlands. a) Montane sites b) Subalpine sites. Species are listed in order of their contribution to the mean similarity amongst the sites in each group, up to a cumulative contribution of 90% in the case of montane sites and 95% for subalpine sites. 'Si' stands for similarity and represents the contribution of that species to the average similarity of the group. The neighbouring column gives the ratio of that species similarity contribution to the standard deviation of its contribution.

(a) Montane sites. Average similarity = 35.82

Species	Mean Cover(%)	Si	Si/SD(Si)	Cumulative (%)
Leptospermum grandifolium	23.54	21.2	1.66	59.30
Carex appressa	7.88	3.9	0.64	70.19
Richea victoriana	5.25	2.9	0.35	78.32
Blechnum penna-marina	1.00	0.9	1.76	80.97
Nothofagus cunninghamii	3.00	0.8	0.23	83.30
Wittsteinia vacciniacea	1.96	0.7	0.92	85.16
Tasmannia xerophila	0.88	*0.6*	*0.70*	*86.80*
Deyeuxia brachyathera	0.42	0.6	1.36	88.36
Polytrichum commune	0.71	0.5	0.82	89.90

(b) Subalpine sites. Average similarity = 65.52

Species	Mean Cover(%)	Si	Si/SD(Si)	Cumulative(%)
Empodisma minus	31.88	41.0	2.86	62.57
Epacris paludosa	17.50	14.7	1.38	84.94
Richea continentis	5.06	3.1	0.74	89.63
Baeckea gunniana	3.31	1.9	1.18	92.56
Erigeron paludicola	0.69	0.6	1.59	93.54
Astelia alpina	0.88	0.6	0.69	94.42

Table 4. Mean cover (%) of important species discriminating between the montane and subalpine peatland sites. Species are listed in order of their contribution to the mean dissimilarity of the groups, up to a cumulative contribution of 90%. 'Di' stands for dissimilarity and represents that species contribution to the average dissimilarity between the groups. The neighbouring column gives the ratio of that species dissimilarity contribution to the standard deviation of its contribution.
Average dissimilarity = 94.42%

Species	Montane Cover(%)	Subalpine Cover(%)	Di	Di/SD (Di)	Cumulative (%)
Empodisma minus	0.00	31.88	25.20	3.28	26.69
Leptospermum grandifolium	23.54	0.06	17.86	1.32	45.61
Epacris paludosa	1.58	17.50	12.23	1.49	58.56
Richea continentis	3.13	5.06	5.94	0.76	64.85
Carex appressa	7.88	0.25	5.84	0.74	71.03
Richea victoriana	5.25	0.31	4.63	0.74	75.93
Gleichenia dicarpa	3.17	0.00	2.62	0.30	78.70
Nothofagus cunninghamii	3.00	0.00	2.59	0.52	81.44
Baeckea gunniana	0.00	3.31	2.44	0.83	84.03
Astelia alpina	1.25	0.88	1.59	0.53	85.71
Wittsteinia vacciniacea	1.96	0.06	1.55	0.45	87.36
Coprosma granadensis	1.79	0.38	1.34	0.47	88.78
Blechnum penna-marina	1.00	0.00	0.77	1.24	89.60

composition similarity and are positioned in the ordination space at the lower value end of the shade and canopy height vectors. One of the Tom Burns Creek plots (site 8) is the out-group in the montane branch of the dendrogram, but it has been included in this group because of its position along the shade vector. These are the montane 'treeless' peatlands.

The remainder of the montane sites (3, 4, 7, 12 & 17–19) form a cluster at approximately 55% similarity. In the ordination space, they are positioned at the high value end of the shade /canopy height vectors and have therefore been classified as the montane 'rainforest' peatlands.

The same method was used to divide subalpine sites into subgroups, although the distinction is not as clear due to the greater overall similarity of subalpine sites (Table 3b & Figure 4). The Lake Mountain plots (sites 9–11) and one of the Mount Bullfight plots (site 14) form a cluster at 70% similarity and are positioned in ordination space at the higher end of the water cover vector (Figure 3). The Storm Creek plot is an out-group in the dendrogram, but is positioned at the high end of the water cover vector and thus has been included. These sites comprise the subalpine 'valley-floor' peatlands. The remaining Mount Bullfight sites (13 & 15) form a separate cluster and the Mount Torbreck site (16) is an out-group. All three fall at the opposite end of the water cover vector and are referred to as the subalpine 'hillslope' peatlands.

Subgroup descriptions, characteristics and important species

1) Montane 'Treeless' Peatlands:-

These are characterised by stunted *Leptospermum grandifolium* (< 2 m), *Richea victoriana*, *Carex appressa*, *Coprosma granadensis* and *Blechnum penna-marina*. A total of 43 species were recorded, including three exotics (Table 6). The sites in this group were typically wetter. In the absence of a tree canopy they are also subjected to cold-air drainage and consequent 'frost' effects. Included in this group is the Tom Burns Creek *Gleichenia dicarpa* dominated peatland (site 8), which contained abundant juvenile and stunted *Leptospermum grandifolium* shrubs and occasional *Gahnia sieberiana* (Table 7).

2) Montane 'Rainforest' Peatlands:-

This peatland type generally contained a canopy of tall *Leptospermum grandifolium*. Some also had *Nothofagus cunninghamii* as a canopy species. Understorey composition in these sites was variable but consistently included *Carex appressa* and *Blechnum penna-marina*. Other important species were *Wittsteinia vacciniacea*, *Deyeuxia brachyathera* and *Libertia pulchella*. This was the most species rich group on arguably the shallowest peats. Mean species richness per site was 20 and a total of 52 taxa were recorded at the seven sites. Five of these were introduced species.

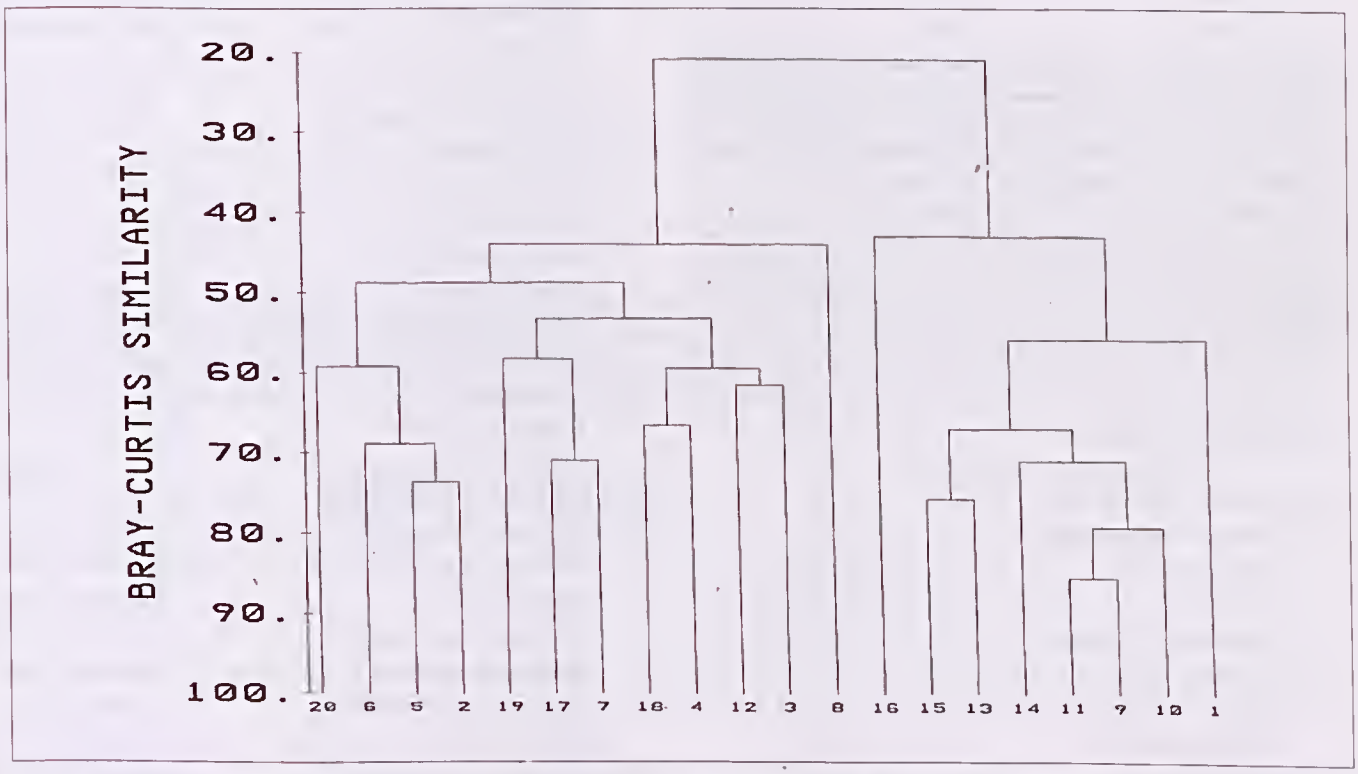


Fig. 4. Dendrogram (group average linkage, using Bray/Curtis) of the Central Highlands *Sphagnum* peatlands based on species presence /absence data. The sites separate into two groups at approximately 20% similarity. In general the subalpine sites (right-hand branch) cluster at higher similarity levels.

3) Subalpine 'Hill-slope' Peatlands:-

This group of peatlands is located on gentle slopes with a generally south or south-easterly aspect in treeless wet heath vegetation. A total of 24 species were recorded in this subgroup, none of which are exotic. The dominant species were *Empodisma minus* and the shrubs *Epacris paludosa*, *Baeckea gunniana* and *Richea continentis* (Table 8; Appendix 1). *Sphagnum cristatum* formed an almost continuous cushion under and between these shrubs.

4) Subalpine 'Valley-floor' Peatlands:-

These contained similar amounts of *Empodisma minus* and *Richea continentis* to the above community, but much less *Epacris paludosa* and *Baeckea gunniana*. Shrubs were much reduced in height (< 0.50 m) and overall abundance. The typical hummock-hollow topography characteristic of many *Sphagnum* peatlands was apparent. This group contains the only sites in which two species of *Sphagnum* were recorded. *Sphagnum novo-zelandicum* dominated many of the shallow pools and hollows of the five sites in this group. Overall species richness was greater than in hill-slope peatlands (35 species). The variability in microtopography resulted in a greater variety of sedges, lilies and herbs, including *Astelia alpina*, *Erigeron paludicola*, *Carex gaudichaudiana*, *Asperula gunnii* and *Juncus sandwithii*.

Table 5. Mean cover of selected *Sphagnum* peatlands species by altitude and shade: (a) according to abundance along the fitted vector for altitude ranging from low (segment 1) to high (segment 7); (b) according to abundance along the fitted vector for shade from low (segment 1) to high (segment 8).
The abundance of each species was standardised to range from 0 to 1. The standardised values were then allocated to one of five classes with upper limits 0.2, 0.4, 0.6, 0.8, and 1.0 (classes 1–5 respectively). A dash indicates that species was absent from that segment.

(a) Altitude (low to high)		1 2 3 4 5 6 7
LOW	*Blechnum pennamarina*	5 3 1 1 1 _ _
	Leptospermum grandifolium	5 3 1 2 2 _ 1
	Libertia pulchella	5 3 _ 3 _ _ _
	Poa ensiformis	5 3 4 3 5 _ _
	Nothofagus cunninghamii	2 _ 5 5 1 _ _
	Wittsteinia vaccinaceae	4 1 1 5 1 _ 1
	Richea victoriana	_ 5 5 2 _ 1 _
	Hypericum japonicum	3 5 4 3 5 2 _
	Carex appressa	1 1 1 5 1 1 1
	Polytrichum commune	2 3 5 4 _ 2 _
	Coprosma granadensis	_ 1 2 5 1 1 1
	Oreomyrrhis ciliata	_ _ 5 2 _ 2 _
	Isolepis aucklandica	2 2 5 3 _ 2 2
	Gonocarpus micranthus	_ 5 4 _ _ 5 _
	Erigeron paludicola	2 3 5 4 _ 5 2
	Astelia alpina	_ _ _ 5 _ 2 2
	Carex gaudichaudiana	_ _ 5 _ _ 4 1
	Luzula modesta	_ _ 2 3 5 4 2
	Richea continentis	_ _ _ _ 5 1 1
	Asperula gunnii	_ _ _ 2 _ 5 5
	Epacris paludosa	_ 1 _ 1 1 3 5
	Oreobolus oxycarpus	_ _ _ _ _ 5 4
	Callistemon pityoides	_ _ _ _ _ 3 5
	Juncus sandwithii	_ _ _ _ _ 5 4
	Chionogentias muelleriana	_ _ _ _ _ 5 4
	Empodisma minus	_ _ _ _ _ 4 5
	Poa costiniana	_ _ _ _ _ 3 5
HIGH	*Baeckea gunniana*	_ _ _ _ _ 2 5

(b) Shade (low to high)		1 2 3 4 5 6 7 8
LOW	*Baeckea gunniana*	5 2 2 _ _ _ _ _
	Callistemon pityoides	4 5 _ _ _ _ _ _
	Empodisma minus	5 5 1 _ _ _ _ _
	Poa costiniana	1 5 2 _ _ _ _ _
	Epacris paludosa	5 4 1 4 1 _ 1 _
	Juncus sandwithii	5 4 4 _ _ _ _ _
	Oreobolus oxycarpus	5 4 4 _ _ _ _ _
	Asperula gunnii	5 5 4 _ _ _ 4 _
	Carex gaudichaudiana	4 _ 5 _ _ _ _ 1
	Gonocarpus micranthus	2 2 _ _ 2 5 _ _
	Richea continentis	1 3 3 _ 5 _ _ _
	Luzula modesta	3 4 4 _ 5 _ 4 2
	Erigeron paludicola	2 5 3 _ 5 3 2 4
	Isolepis aucklandica	2 4 2 4 5 4 4 3
	Richea victoriana	1 _ 3 5 2 5 1 _
	Oreomyrrhis ciliata	_ _ 5 _ 2 _ _ 2
	Polytrichum commune	1 1 1 5 2 1 1 1
	Astelia alpina	1 1 1 _ _ _ 5 _
	Hypericum japonicum	_ _ 5 5 5 5 _ 3
	Poa ensiformis	_ _ 3 5 4 5 3 3
	Deyeuxia brachyathera	_ _ 3 5 2 5 5 5
	Gonocarpus montanus	_ _ _ _ 2 5 _ 2
	Coprosma granadensis	1 1 1 _ 2 1 2 5
	Carex appressa	_ 1 1 5 1 1 5 4
	Wittsteinia vaccinaceae	1 _ _ 1 1 1 5 1
	Blechnum pennamarina	_ _ 1 1 1 5 1 3
	Leptospermum grandifolium	_ 1 _ 2 2 5 2 5
	Libertia pulchella	_ _ _ _ _ 5 5 3
HIGH	*Nothofagus cunninghamii*	_ _ _ _ 1 _ 5 3

Table 6. Summary of environmental variables recorded for each peatland subgroup, giving ranges, (averages in bold).

Peatland community type	Total no. of sites	*Sphagnum* cover (%)	Altitude (m)	pH	Peat depth (m)	Shade cover (%)	Species richness
Montane 'treeless'	5	25–75	1085–1135	4.8–5.5	0.83–1.2+	0–2.5	13–23
		52	**1103**	**5.3**	**>0.93**	**1.3**	**18**
Montane 'rainforest'	7	25–100	910–1290	4.2–5.5	0.71–1.18	2.5–62.5	13–25
		54	**1134**	**4.8**	**0.98**	**24.6**	**20**
Subalpine 'hill-slope'	3	25–75	1420–1430	4.7–5.5	0.95–1.2+	0.5–15	11–16
		46	**1423**	**5.1**	**>1.15**	**6.0**	**14**
Subalpine 'valley-floor'	5	25–75	1175–1430	4.4–5.5	0.89–1.2+	0.5–2.5	14–20
		52	**1360**	**4.8**	**>1.07**	**0.9**	**17**

Table 7. Mean cover (%) of important species discriminating between the 'rainforest' and 'treeless' montane peatland sites.
Species are listed in order of their contribution to the mean dissimilarity amongst sites, up to a cumulative contribution of 85%. 'Di' stands for dissimilarity and represents that species contribution to the average dissimilarity between the groups. The neighbouring column gives the ratio of that species dissimilarity contribution to the standard deviation of its contribution. Average dissimilarity = 67.03

Species	'rainforest' sites cover (%)	'treeless' sites cover (%)	Di	Di/SD(Di)	Cumulative(%)
Leptospermum grandifolium	28.57	16.5	14.99	0.91	22.37
Carex appressa	7.29	8.70	8.68	1.03	35.31
Richea victoriana	2.21	9.50	7.86	1.18	47.03
Gleichenia dicarpa	0.00	7.60	6.17	0.50	56.24
Nothofagus cunninghamii	5.14	0.00	4.74	0.74	63.30
Richea continentis	5.36	0.00	4.47	0.40	69.97
Coprosma granadensis	0.43	3.70	2.71	0.69	74.01
Wittsteinia vacciniacea	3.14	0.30	2.44	0.54	77.65
Epacris paludosa	2.64	0.10	2.14	0.51	80.85
Astelia alpina	2.14	0.00	1.76	0.40	83.47
Erigeron paludicola	0.14	1.30	0.92	1.16	84.84

Table 8. Mean cover (%) of important species discriminating between subalpine hill-slope and valley-floor peatland sites.
Species are listed in order of their contribution to the mean dissimilarity amongst sites, up to a cumulative contribution of 90%. 'Di' stands for dissimilarity and represents that species contribution to the average dissimilarity between the groups. The neighbouring column gives the ratio of that species dissimilarity contribution to the standard deviation of its contribution. Average dissimilarity = 37.87

Species	Valley-floor sites cover %	Hill-slope ssites cover %	Di	Di/SD (Di)	Cumulative(%)
Epacris paludosa	8.75	30.00	15.18	1.77	40.08
Empodisma minus	31.88	30.00	8.30	0.79	62.01
Richea continentis	5.63	6.00	4.43	0.86	73.72
Baeckea gunniana	1.50	6.67	3.55	0.86	83.11
Astelia alpina	1.50	0.33	0.88	1.05	85.42
Poa costiniana	0.88	0.50	0.50	0.69	86.73
Erigeron paludicola	1.00	0.33	0.47	0.70	87.98
Juncus sandwithii	0.50	0.00	0.39	3.87	89.02
Celmisia pugioniformis	0.38	0.00	0.30	1.48	89.82

Both subalpine valley floor peatlands and treeless montane communities were positioned at the high value end of the water vector. This is likely to be related to landscape position, these communities being situated in lower topographic positions, in larger open cold-air drainage hollows and on deeper peats. Peat depths in excess of 1.2 m were recorded at many sites. Mean depths were similar amongst the four subgroups and was not a significant differentiating variable in ordination analysis. However, the actual depth range was less in montane rainforest peatlands than in the other three subgroups (Table 6).

The pH measurements were variable in all four peatland types. There was no clear trend and mean figures ranged from 4.8 in montane rainforest and subalpine valley-floor systems to 5.3 in treeless montane peatlands.

Species richness was significantly greater in montane as opposed to subalpine systems ($t = -2.149$; $p = 0.045$; $df = 18$). Amongst the montane site group, rainforest systems displayed higher species richness than treeless, and valley-floor peatlands were richer in the subalpine group.

Discussion

Variation within the Central Highlands region

Floristic composition of *Sphagnum*-dominated plant communities varies considerably within the Central Highlands of Victoria. The key factors appear to be altitude-related. Altitude is a surrogate in the analysis for climate factors such as temperature, frost intensity, and duration of snow cover. The variables shade, canopy height, aspect and slope were also important in explaining vegetation patterns.

Shade and canopy height are indirectly tied to climate, by facilitating the existence of a humid micro-climate, reducing evapotranspiration and *Sphagnum* dessication, and, by moderating temperature variation and reducing frost exposure. The montane 'treeless' peatland communities all occurred in broad natural forest gaps. Distances from forest fringe to forest fringe were between 40 and 150 m. Frost and anoxic water-logged peats are thought to act in unison to determine plant composition, by excluding trees and limiting shrub growth (Farrell and Ashton 1973, Ashton and Hargreaves 1983). However, the palaeoecological evidence suggests that the substratum has been wet enough to prevent tree establishment for thousands of years (McKenzie 1997) and the absence of trees has been reinforced by temperature limitations due to cold air pooling., Where present in montane treeless peatlands, the shrub *Leptospermum grandifolium* was typically stunted, bushier in growth habit, and associated with other shrubs like *Richea victoriana* and *Tasmannia xerophila*. At the peatland fringe, *Leptospermum* achieved its more familiar form (6–7 m), probably partly in response to access to richer mineral soils. In narrower gullies and depressions, *Leptospermum* and *Nothofagus cunninghamii* form a low open forest of between 3 and 7 m, assisted by the associated milder microclimate. The ground layer in this context consists of abundant *Sphagnum cristatum* and *Carex appressa*, with a reduced shrub presence.

Aspect and slope were important factors in subalpine peatlands. The 'hill-slope' *Sphagnum* communities observed at Mount Torbreck and Mount Bullfight occur on gentle to moderate southerly to easterly slopes where they are protected from desiccation by the surrounding *Eucalyptus pauciflora* heathy forest. They are also assisted by seepage from the ridges above and therefore remain moist even through drier months. Similar hill-slope, seepage, or 'raised bogs' occur throughout the alpine and subalpine areas of Victoria and New South Wales, although composition varies slightly (McDougall 1982, Wahren et al. 1999, Costin et al. 2000). Subalpine valley floor peatlands are associated with less slope, more surface water, and display greater variation in microtopography.

Successional Development

Vegetation patterns across the entire region appear to have been shaped by the large landscape-scale fires of the late 19th and early 20th century, particularly those in 1926 and 1939 (LCC 1973, Rundle 1977, Ashton & Hargreaves 1983, Ashton 2000). Most peatland sites examined contained large stumps or 'stags' at their perimeter, probably formerly *Eucalyptus delegatensis*. Many burnt trunks have collapsed into and across the peatlands as a result of decay or the salvage logging operations that followed the 1939 fires. In some cases this has further impeded drainage, possibly facilitated *Sphagnum* growth, and provided substrate for shrub establishment (Agnew et al. 1993).

Perhaps of greater significance is the presence of narrower stumps and stags within many treeless montane sites. These are likely to be the remains of trees which would have been at least 7 or 8 m high (Fig. 5). Evidence suggests that these were *Leptospermum grandifolium* and *Nothofagus cunninghamii* (some *Nothofagus* coppicing observed), and that these sites may have once resembled the Keppel Hut site (Fig. 6), an example of the climax of this succession. In the present study, the range of montane sites from 'treeless' to 'rainforest', may relate to seral stages. Narrower sites have quickly reverted to low open forest communities, albeit with a high understorey cover of *Sphagnum*. Some of the slightly broader peatland gullies may also revert to *Leptospermum-Nothofagus* low open forest, given at least 60 years without major disturbance. However, this disturbance-free period seems unlikely given current forestry activity and projected future fire frequencies under climate change (Overpeck et al. 1990).

The severity of the 1939 fires, the scale of post-fire salvage logging and more recent forestry activities, have probably contributed to some montane 'treeless' sites being in the relatively early stages of post-fire succession, even more

than 60 years after the event (Fig. 5). These appear to exist as a type of disclimax community, or in an alternative state, and may never acquire their former structure (Beisner et al. 2003, Suding et al. 2005). *Leptospermum grandifolium* swamps on shallow slopes in the upper head-water streams north and east of Mount Disappointment, on the Hume Range 50 km further west, are considered to have formerly been *Nothofagus cunninghamii-Atherosperma moschatum* cool temperate rainforest prior to a succession of fires between 1898 and 1926 (Ashton 2000). The absence of epacridaceous shrub species such as *Richea victoriana* and *Epacris paludosa* at some of the montane sites may also be due to the high fire frequency in the 80 or 90 years prior to 1939. Species of *Richea* in particular, appear to be very fire-sensitive (Wahren & Walsh 2000).

The landscape position of the Keppel Hut site, in a southern aspect amphitheatre-like gully at 1290 m, surrounded by forested ridges reaching elevations of 1360 m or more, has protected it from recent large fire events. The *Sphagnum* community at this site is situated in a gap of senescent *Nothofagus cunninghamii* of considerable age, and is surrounded by large moss and epiphytic fern encrusted 'stags'(Fig. 6). *Leptospermum grandifolium* was less prevalent at this site, but some individuals present were also of large girth (30 cm diameter). The understorey contained the highest cover of *Astelia alpina* recorded in this study, a species more generally associated with hummocks in higher altitude 'bogs' but occurring as an understorey species in montane communities in Tasmania (Martin 1999).

The Keppel Hut community may be associated with gap formation in an over-mature *Nothofagus cunninghamii* canopy, a process thought to occur after 400–600 years (Howard 1973), but is perhaps more likely to be naturally open, due to the effects of water-logging and peatland dynamics (Van Breeman 1995, Malmer et al. 2003). At the Snobs Creek site, the *Sphagnum* is etiolated due to diminishing light and may therefore be 'migrating' along the forest floor as small gaps open in the riparian rainforest canopy. In this context, *Sphagnum* mosses represent an earlier seral stage or are present as a community component only, rather than constituting the climax vegetation type and system 'driver', as is the case in open subalpine wet heath (Costin 1954, Van Breeman 1995). The optimum canopy cover for *Sphagnum* growth is 20–40%, a higher cover than this and the lack of light will limit its abundance (Whinam & Buxton 1997).

The large 'treeless' montane sites which experience cold air drainage and contain deeper peats (Storm Creek, Tom Burns and Little River), are not part of this dynamic.



Fig. 5. Peatland site 2 looking north from near the south-west margin. Burnt stumps, formerly *Nothofagus cunninghamii* or *Leptospermum grandifolium*, are clearly visible in the foreground and middle distance. *Carex appressa* dominates the ground layer and there is a high continuous cover of *Sphagnum*. *Leptospermum grandifolium* shrubs approximately 2.5 m high are visible in the right and centre distance. These mark the main drainage line. Evidence suggests that the peatland had a *Nothofagus cunninghamii-Leptospermum grandifolium* low open forest canopy prior to the fires in 1939.



Fig. 6. The montane rainforest peatland at Keppel hut (site 17) is surrounded by large senescing *Nothofagus cunninghamii* and is representative of the subgroup. It is likely that site no. 2 (Fig.5) may have resembled this site before the fires of 1926 and 1939. Light snow is lying on the hummocks of *Sphagnum cristatum* (June, 2003).

Hence, subalpine species exist both within and at the fringe of these peatlands. This is particularly true of the Storm Creek peatland, which was more floristically similar to the subalpine sites than to other sites at similar altitudes. These species are possibly remnants from earlier in the Holocene when temperatures were cooler and subalpine vegetation extended to lower elevations (McKenzie 1997). While many of these larger montane peatland sites also have large *Eucalyptus delegatensis* stumps at their perimeter on mineral soils, they do not show evidence of a former 'within peatland' *Nothofagus* occupation.

Amongst the 'treeless' montane *Sphagnum* peatlands, the Little River site is particularly interesting, partially due to its landscape position, and because it demonstrates the influence of cold-air drainage on vegetation patterns (Fig. 7). It is located in a broad valley at approximately 1100 m and is surrounded on three sides by ridge-tops that rise to well over 1200 m, reaching 1380 m on the eastern side. The *Sphagnum* peatlands are along the valley floor, surrounded by the relatively cold-tolerant *Eucalyptus perriniana* which forms a low open forest with an understorey of heath shrubs such as *Leionema phylicifolium* and *Pultenaea mmelleri*. There is no *Nothofagus cunninghamii* in the vicinity of these peatlands, and only limited stunted *Leptospermum grandifolium*.

Species richness patterns within peatlands

Sphagnum peatland plant communities are not species-rich by nature (Joosten & Clarke 2002). The higher species richness in montane, compared to subalpine systems in the Central Highlands, is perhaps to be expected given higher mean temperatures, a longer growing season, and conditions generally less demanding for plants. Plant exposure to frost may actually be greater in montane 'cold-air' drainage hollows than subalpine ones because they are not protected by an insulating layer of snow for several months over winter (Williams 1987). This, however, does not seem to be manifest in reduced diversity and is perhaps more likely to enhance species richness by limiting shrub dominance. Within the montane sites group, 'rainforest' peatland communities appeared to be richer in species. The narrower nature of these, and their proximity to the wet sclerophyll forest ecotone may partly explain this. Many non-wetland species were recorded at these sites. There was more evidence of disturbance in and around montane sites (forestry, deer, rabbits) and this may be a factor contributing to higher species richness.

The montane 'rainforest' peatlands with large mature *Nothofagus* and *Leptospermum* individuals, contained sub-communities on raised roots and around tree bases including species such as *Wittsteinia vacciniacea*, *Libertia pulchella*



Fig. 7. Treeless montane peatland in the upper reaches of the Little River (site 20) looking south-east from the head of the system. *Eucalyptus perriniana* forest surrounds the peatland on higher ground either side. *Richea victoriana* is visible at the fringe. The centre of the peatland is dominated by *Carex appressa*, *Carex gaudichaudiana* and *Sphagnum cristatum*. Stunted *Leptospermum grandifolium* is just visible at the far end.

and *Carex breviculmis*. Epacridaceous species were rare and sparse at these sites. Bare peat patches contain *Isolepis aucklandica* and *Epilobium gunniannm*, while *Coprosma granadensis* and *Erigeron paludicola* occur in *Sphagnum* cushions. Hence, niche diversity and variability in resource availability probably contributes to the higher species richness.

Subalpine valley-floor peatlands (Fig. 8) displayed a high species richness relative to hill-slope communities, probably as a result of a similar micro-habitat diversity to the above mentioned montane 'rainforest' systems. Shallow rooted species like *Aspernla gunnii*, *Erigeron paludicola*, *Luzula modesta* and the lily *Astelia alpina*, were often present in hummocks of *Sphagnum cristatum*. Hollows contained *Sphagnum novo-zelandicum*, *Carex gaudichaudiana* and *Juncus sandwithii*, with *Oreobolus* species often found at the edge of hollows adjacent to *Empodisma minus*. Peatland site no. 14, at Mount Bullfight, contained far less *Sphagnum novo-zelandicum*. In its place, hollows contained *Oreobolus oxycarpus* cushions and *Ranunculus collinus*, *Epilobium gunniannm* and *Hypericum japonicum*. These sub-communities containing *Oreobolus* and rhizomatous herbs are reminiscent of peat and gravel pavements that occur in similar landscape settings on the Bogong High Plains in north-east Victoria and at Kosciusko in New South Wales (Costin 1954, Wimbush & Costin 1979, McDougall 1982, Wahren et al. 1999). Where they occur in these regions, they are thought to be associated with earlier seral stages, and a precursor to *Sphagnum* colonisation. *Caltha introloba* is a component of this community elsewhere in subalpine and alpine areas of Victoria and southern New South Wales (Wimbush & Costin 1979, McDougall 1982, Walsh et al. 1986), but seems to be absent from the Central Highlands.

Hill-slope subalpine peatlands tended to be dominated by the shrubs *Richea continentis*, *Epacris paludosa* and *Baeckea gunniana*, perhaps a response to more humified peats (Malmer et al. 2003). Greater shrub growth in these communities is characteristic of soligenous peatlands or 'sloping' mires, where greater peat water flow, in response to slope, enhances nutrient availability in the rhizosphere (Gore 1983a, Charman 2000, Joosten & Clarke 2002). These communities are less species-rich but still maintain a high *Sphagnum* cover.

Comparison with other highland regions in Victoria and southern New South Wales

Sphagnum-dominated peatlands in the Central Highlands appear to display mixed floristic affinities. Subalpine communities are similar to those occurring at Mount Baw Baw, and to a lesser extent, on the Bogong High Plains and in the Kosciuszko region. Subalpine systems, while containing many of the same species (*Richea*, *Baeckea*, *Empodisma*, *Astelia*), also contain a second *Sphagnum* species (*Sphagnum novo-zelandicum*), which is abundant in hollows and shallow pools, but which is much less conspicuous in the peatlands of north-eastern Victoria. This hummock /hollow partitioning of *Sphagnum* species, common in the northern hemisphere, seems to be rare in Australia (Whinam & Hope 2005).

The montane systems in this study are quite different from subalpine peatlands both within this region and further to the north-east, but appear to be similar to those systems in the upper Thompson River and Yarra headwaters region, to the west of the Baw Baw plateau (Willis 1945, Walsh et al. 1986). They also differ in composition from montane systems found in southern New South Wales (Costin 1954, Whinam & Hope 2005), and further east in Victoria (Ladd 1979, Whinam & Chilcott 2002, Shannon & Morgan unpublished data).

The general floristic affinities of the Central Highlands region with Tasmania (Busby & Brown 1994) apply equally to wet heathlands and *Sphagnum* peatlands (Costin 1957, 1962). *Nothofagus cunninghamii* is a component of montane 'rainforest' peatlands and is also present in vegetation fringing treeless peatlands in montane and subalpine areas. Many species with Tasmanian associations are also either community members or present in surrounding vegetation. The prostrate, scrambling epacrid species *Trochocarpa clarkei* is a local endemic and frequently found at peatland margins in both montane and subalpine areas. It is the only Victorian representative of the genus, other members being prevalent in Tasmania. There are several species of *Richea* associated with peatlands in Tasmania (Whinam et al. 2001) and two of these occur in the Central Highlands, though only one occurs in peatlands further to the north-east (McDougall 1982, Walsh et al. 1986).

The Tasmanian floristic affinities have been attributed to the more maritime climate of the southern end of the mainland highland regions (Costin 1957, 1962, Williams & Costin 1994, Kirkpatrick & Bridle 1998, 1999). The Kosciusko and Bogong High Plains regions are subject to a more continental climate with greater precipitation variability and colder winter temperatures. Summer precipitation totals are higher and less variable in southern areas, whereas snow cover duration is greater in the more continental areas further north (Kirkpatrick & Bridle 1998).

Four of the sites in this study were the subject of earlier palaeoecological analysis (Ashton & Hargreaves 1983, McKenzie 1997). The basal layers of peat cores taken from Tom Burns Creek were estimated to be 32 000 years old, and those at Storm Creek 17 000 years (McKenzie 1997), suggesting that they have functioned as peatlands for longer than the higher altitude systems in the Kosciusko and Bogong regions, which are generally believed to have developed over the 11 000 years since the end of the last glacial period (Kershaw & Strickland 1989, Martin 1999).

Overall condition

In relative terms, the peatland ecosystems of the Central Highlands region are in a good condition. Limited livestock

grazing occurred across the area but is not thought to have been as intensive as in the eastern highlands (Lawrence 1999, Wahren et al. 1999). This activity decreased in the forests in the 1930s, and had ceased altogether in subalpine areas by the middle of the 1960s (Ashton & Hargreaves 1983). 'Pugging', exposed bare peat, and the common introduced 'pasture' species associated with livestock grazing and degraded systems elsewhere are absent, except for some small isolated patches linked to introduced deer (authors pers. obs.). The dense forests that surround the Central Highlands peatlands have, in this sense, protected them.

Fires burnt nearly 3 million hectares of vegetation across highland areas of southern New South Wales, Australian Capital Territory and eastern Victoria in January 2003 (Esplin 2003). Large areas of peatland were also burnt in these fires (Hope & Whinam 2005, Tolsma et al. 2005) and are thus now in the fragile, early stages of post-fire regeneration. At the time of writing (December 2006), extensive fires were burning in sections of the Alpine National Park north of Gippsland. It is likely that these have burnt areas of peatland. In contrast, the peatlands of the Central Highlands and Baw Baw Plateau have not experienced fire since 1939.

The impact of past and current forestry activities in montane areas on peatland hydrology, processes and composition is hard to determine. In some cases fallen logs have impeded drainage, favourably altering hydrology and enhancing mire activity. However, the scale and intensity of current activities is still of concern. Several of the peatlands surveyed were adjacent to recently cleared logging coupes, or regrowth forest less than 30 years old, and this has implications for the supply of seepage water to these systems (Vertessy et al. 2001), not to mention shorter-term alterations to microclimate. In palaeoecological studies, an increased charcoal presence is sometimes linked to a combination of climate fluctuation and anthropogenic activity. Furthermore, it often coincides with a subsequent increase in *Sphagnum* derived peat in the profile above. However, in most of these examples the surrounding catchment slopes were permanently cleared of trees (Martin 1999, McGlone et al. 1997, McGlone & Wilmshurst 1999).

Anthropogenic activity (timber extraction, frequent fire) has been focussed in the surrounding forests and the impacts appear to have been greater there, and perhaps less within actual peatland systems. The presence of exotic plant species within those systems surveyed is relatively low, although they are quite well represented in logging regrowth forest. There is some evidence of illegal *Sphagnum* moss harvesting on small scales at one or two sites (Whinam et al. 2003). Introduced herbivores such as rabbits and hares are perhaps of concern. Damage caused by them is evident in some grassy clearings at peatland /forest margins and sometimes within peatlands on *Empodisma minus* mats (droppings).

Conclusion

McKenzie (1997) highlighted the palaeoecological significance of several of the peatlands within the region. They have a long history, which began before the last glacial maximum. Much important information on past vegetation patterns and climates is stored in the peat layers of these sites.

There are several significant areas. Storm Creek and Tom Burns Creek have already been identified as significant Victorian wetlands (ANCA 1996). The mature *Nothofagus cunninghamii* 'rainforest' peatland at Keppel Hut seems to have escaped recent major fires (1939). Sites observed in the upper reaches of the Little River are of interest as much for their landscape setting and associated surrounding vegetation. Several key species have interesting distributions across the region: *Sphagnum novo-zelandicum* is noticeably more prevalent at the southern end of the study area (Lake Mountain and Storm Creek sites). *Richea continentis*, a key species in alpine and subalpine systems in north-east Victoria, is present at the subalpine sites examined, but is replaced by *Richea victoriana* in montane sites and at Storm Creek. It is interesting to note that the Mount Bullfight valley-floor site was the only one in which both species were present.

Sphagnum 'bog' communities are listed as threatened under the Victorian Flora and Fauna Guarantee Act (1988). Many in the Central Highlands area are outside existing reserves and deserve more formal protection, particularly those at Keppel Hut and Little River (Table 1). Mire systems in south-eastern Australia face an uncertain future given their already marginal status (Whinam et al. 2001) and the unfavourable climate change outlook for south-east Australia (Whetton et al. 1996). However, the palaeoecological evidence from some of these peatlands suggests that they are resilient to large climate fluctuations and changes in the vegetation of the surrounding landscape (McKenzie 1997, 2002). Provided anthropogenic interference is minimised through appropriate management, they will continue to exist and function as peatlands. Efforts should be made to ensure the protection of these previously undescribed peatlands.

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Fig. 8. A good example of a subalpine valley-floor peatland at Mt Bullfight (site 14), showing a well developed 'bog' pool surrounded by *Sphagnum cristatum*, *Empodisma minus*, *Richea continentis*, *Epacris paludosa*, *Poa costiniana* and *Carex appressa*.

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Vegetation of montane bogs in east-flowing catchments of northern New England, New South Wales

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Abstract: The floristics of the montane bogs in east-flowing catchments of northern New England, north-eastern New South Wales (lat 28° 47'–31° 25' S; long 151° 50'–152° 30' E), are described from 62 full floristic survey sites (20 x 20 m in area). Eight vegetation communities are based on flexible UPGMA analysis of cover-abundance scores of vascular plant taxa. Shrub species make up 26% of the flora and herb species 69%, with the remaining taxa trees, climbers or vines. Shrub species were of little diagnostic value, as a few common dominants were shared across most communities. The herbaceous layer was found to be of better circumscriptive value. Communities described (based on dominant herbaceous species) are: (1) *Themeda australis – Gonocarpus micranthus*, (2) *Baumea articulata – Baloskion stenocoleum*, (3) *Lepidosperma limicola – Baloskion stenocoleum*, (4) *Baloskion fimbriatum – Lomandra longifolia*, (5) *Lepyrodia scariosa – Blandfordia grandiflora*, (6) *Lepidosperma gunnii – Lepidosperma scariosa*, (7) *Baloskion stenocoleum – Empodisma minus*, (8) *Lepidosperma limicola – Xyris operculata*. The mean annual moisture index was found to account for 26% of the variation in species density.

These montane bog systems are some of the richest in Australia, with a high number of rare and restricted taxa. They are vulnerable to both present landuse practices and future changes in climate, are restricted in area, and need further conservation efforts to ensure their long-term survival.

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Introduction

According to the RAMSAR definition, wetlands consist of 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres'. Despite this encompassing definition, wetlands only occupy 4% of the global land surface (Weltzin et al. 2000).

In Australia, only a very small amount of the land area is in montane environments, and it is not surprising that temporary montane wetlands are sparsely distributed, and rare in the landscape (Jarman et al. 1988; Whinam & Hope 2005). Although there are some outliers in western Victoria and parts of eastern South Australia, montane wetlands are restricted to the Great Dividing Range south from Stanthorpe in Queensland, to east of Melbourne in Victoria, and to upland areas of Tasmania (Fig. 1).

On the Northern Tablelands of New South Wales natural wetlands include bogs (generally nutrient-poor, low pH and dominated by sclerophyllous shrubs) and fens (generally more nutrient-rich with higher pH and dominated by soft-leaved tussock sedges and grasses), as well as lagoons (areas of perennial or ephemeral open water). When describing the montane wetland environments of New South Wales, Keith (2004) retained these terms and their associated hydro-chemical meanings, though the chemical distinction between these types of wetlands is often indistinct in the Australian literature (Jarman et al. 1988; Whinam & Hope 2005). Bogs and fens are sometimes collectively termed mires, and in the European context, ombrotrophic mires (often nutrient-poor and low pH) are termed 'bogs', and minerotrophic mires (often more nutrient-rich with higher pH), are termed 'fens' (Wheeler & Proctor 2000; Økland et al. 2001).

Cool or cold wet climates with slow runoff and low evapotranspiration are most favourable for peat development and many Australian montane wetlands have minor to significant amounts of peat (Jarman et al. 1988; Keith 2004; Whinam & Hope 2005). These montane peat-forming wetlands can be complex hydrological and edaphic environments commonly consisting of mosaics of grasslands, heaths, herbfields or fens dominated by sedges, or fairly uniform compositional units (Wahren et al. 1999; Keith 2004; Williams & Clarke 2006). The description of temporary montane wetlands has often concentrated on vegetation structure and life form (Whinam & Hope 2005) and many of these systems are labelled sedgelands, wet heaths, sedge-heaths or heath swamps (Beadle 1981; Binns 1992; Binns 1995; Chapman & Binns 1995; Benson & Ashby 2000; Clarke et al. 2000; Zoete 2000).

Australian montane wetlands would be considered significant if only due to their rarity in the landscape alone (Wahren et al. 1999), but many of these environments are also threatened by anthropogenic landuse practices such as grazing, draining and burning (Benson & Ashby 2000; Whinam et al. 2001; Whinam & Chilcott 2002; Whinam et al. 2002; Hope & Kershaw 2005). As a result of such threats, *Montane peatlands and swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and the Australian Alps bioregions* have been listed (17 December 2004) as an Endangered Ecological Community under the NSW *Threatened Species Conservation Act* (1995).

Within the New England Bioregion many montane bogs, including some of the most extensive, occur where *Sphagnum* is not always a dominant component of the vegetation (Whinam & Hope 2005). The New England Bioregion represents the northern limit of this vegetation type in Australia (Jarman et al. 1988; Whinam & Chilcott 2002) and many floristic investigations have been undertaken there, mostly within bogs (Millington 1954; Binns 1992; Binns 1995; Chapman & Binns 1995; Hunter 1998; Hunter 1999; Hunter et al. 1999; Benson & Ashby 2000; Clarke *et al.* 2000; Hunter 2000; Hunter 2002; Sheringham & Hunter 2002; Hunter 2004ab; Hunter 2005ab). Whinam and Chilcott (2002) provided a broader floristic context for the New South Wales montane bogs, but their investigations were restricted to *Sphagnum*-dominated bogs south of the Sara River, north-east of Guyra. Bogs in the Barrington Tops area are distinctive (Zoete 2000) and shown in statistical analyses (Whinam & Chilcott 2002) to be allied but separate from the rest of the New England communities. Limited occurrences of montane bogs are known from west-flowing catchments within the New England Bioregion, such as at Torrington (Clarke et al. 1999) and Bolivia Hill (Hunter 2002b) and appear compositionally distinct from those on east-flowing catchments, based on preliminary analyses (Hunter & Bell, unpublished). This paper aims to put the floristic composition of the montane bog systems of east-flowing catchments of the northern New England into a regional context.

Methods

Study area

All major bog occurrences in the east-flowing catchments of northern New England, an area of about 300 km north to south and 100 km east to west (lat 28° 47'–31° 25' S; long 151° 50'–152° 30' E) were surveyed. Sixty-two quadrats were placed within 11 bog localities including Backwater, Bald Rock, Basket Swamp, Boonoo Boonoo, Capoompeta, Cathedral Rocks (Ebor), Gibraltar Range, Malara, Mann River, Werrikimbe and Western Washpool areas (Fig. 1). Sampled areas occurred on four bedrock types: basalt, metasediments, acid volcanics and granite. Altitudes ranged from 850 to 1370 m above sea level. The most northerly sampled area at Bald Rock was 260 km from the most southerly at Werrikimbe. Mean annual rainfall ranges from 870 mm to 1750 mm. The number of sites placed on each bedrock type and each site was proportional to area.

Survey methods

Vascular plants and *Sphagnum* were recorded using a modified Braun-Blanquet six point cover abundance scale in 62, 20 x 20 m quadrats. Quadrats were placed randomly within montane bog vegetation. Species not recorded in quadrats but found within the general montane bog environments were recorded opportunistically but not used in formal analyses (Appendix 1). Species nomenclature follows that of Harden (1992–2002) except where recent taxonomic changes have been suggested (PlantNET 2006).

Analyses and data exploration used options available in the PATN Analysis Package (Belbin 2004). For the final presentation, all species and their relative cover scores were included and the analysis performed used the Kulczynski association measure which is recommended for ecological applications (Belbin 2004), along with flexible Unweighted Pair Group arithmetic Averaging (UPGMA) and the default PATN settings. Community structural names are based on the most consistently dominant taxa in the shrub and herbaceous strata. To determine the effects of evapotranspiration, mean moisture index was approximated for each site by the use of BIOCLIM within the ANUCLIM Vers. 5.1 software package (Houlder 2000) and regressed against the number of species per plot (species density).

Results

A total of 438 vascular plant taxa were recorded, 353 within survey sites and 85 opportunistically (Appendix) covering 72 families and 215 genera. The families with the greatest number of taxa were: Poaceae (62 taxa), Cyperaceae (47), Myrtaceae (39), Fabaceae (33), Asteraceae (32), Proteaceae (20), Orchidaceae (15), Juncaceae (14) and Epacridaceae (11). The richest genera were: *Eucalyptus* (19 taxa), *Juncus* (12), *Carex* (8), *Leptospermum* (8), *Austrodanthonia* (7), *Brachyscome* (7), *Isolepis* (7), *Lepidosperma* (7), *Callistemon* (6) and *Pultenaea* (6). 28 taxa (6%) were exotic in origin. Overall 26% of taxa were shrubs and 69% herbs. Species density was found to be highly correlated to the modelled mean moisture index at each site. Mean moisture index itself accounted for 26% of the variation shown in species density scores (Fig. 3).

Vegetation communities

Eight communities were recognised at a dissimilarity measure of 0.75 (Fig. 2). Within communities about 20% of species present were shrubs, though in some communities over 40%

of taxa were shrubs (Table 1). The most characteristic shrub species were (summed cover scores) *Baeckea omissa, Epacris microphylla, Leptospermum gregarium, Leptospermum arachnoides, Callistemon pityoides* and *Hakea macrocarpa*. Characteristic herb layer species were *Baloskion stenocoleum, Goodenia bellidifolia, Lepidosperma limicola, Gonocarpus micranthus* and *Lepyrodia scariosa*. *Sphagnum cristatum* was common, and a major part of many of the communities sampled, including the most northerly. The order of names within the community descriptions reflects the importance of each species in terms of cover and fidelity. The community title includes both dominant overstorey shrub species and the dominant understorey herbs. The shrub component, however, varied less across the communities than the herbaceous layer *Baeckea omissa*, for example, was the dominant shrub in six of the eight communities. Herbaceous species were more diagnostic of differences between communities. Species richness was highest in community 4 and lowest in community 5 (Table 1). Introduced taxa presence was low across all communities (8% for community 1 being the highest) and not apparent in communities 5 and 6. Altitude, geology and rainfall did not appear to be of diagnostic value at this level of analysis (Table 1).

Community 1: Epacris microphylla – Leptospermum arachnoides/Themeda australis – Gonocarpus micranthus

Shrubs: *Epacris microphylla, Leptospermum arachnoides, Baeckea omissa, Leptospermum minutifolium, Hakea microcarpa, Leptospermum gregarium, Banksia spinulosa, Callistemon pityoides, Boronia parviflora, Pimelea linifolia, Petrophile canescens, Persoonia sericea, Banksia cunninghamii.*

Ground cover: *Themeda australis, Gonocarpus micranthus, Goodenia bellidifolia, Ptilothrix deusta, Schoenus apogon, Poa queenslandica, Baloskion stenocoleum, Lepyrodia scariosa, Entolasia stricta, Rhynchospora browniі, Hypericum gramineum, Austrostipa rudis, Lepidosperma elatius, Hydrocotyle peduncularis, Spiranthes sinensis, Xyris operculata, Tricoryne elatior, Schoenus melanostachys, Pratia purpurascens, Patersonia fragilis, Euchiton sphaericus, Austrostipa scabra, Austrodanthonia racemosa, Austrodanthonia monticola, Viola hederacea, Viola betonicifolia, Patersonia sericea, Hydrocotyle geraniifolia, Euchiton gymnocephalus, Dichelachne*

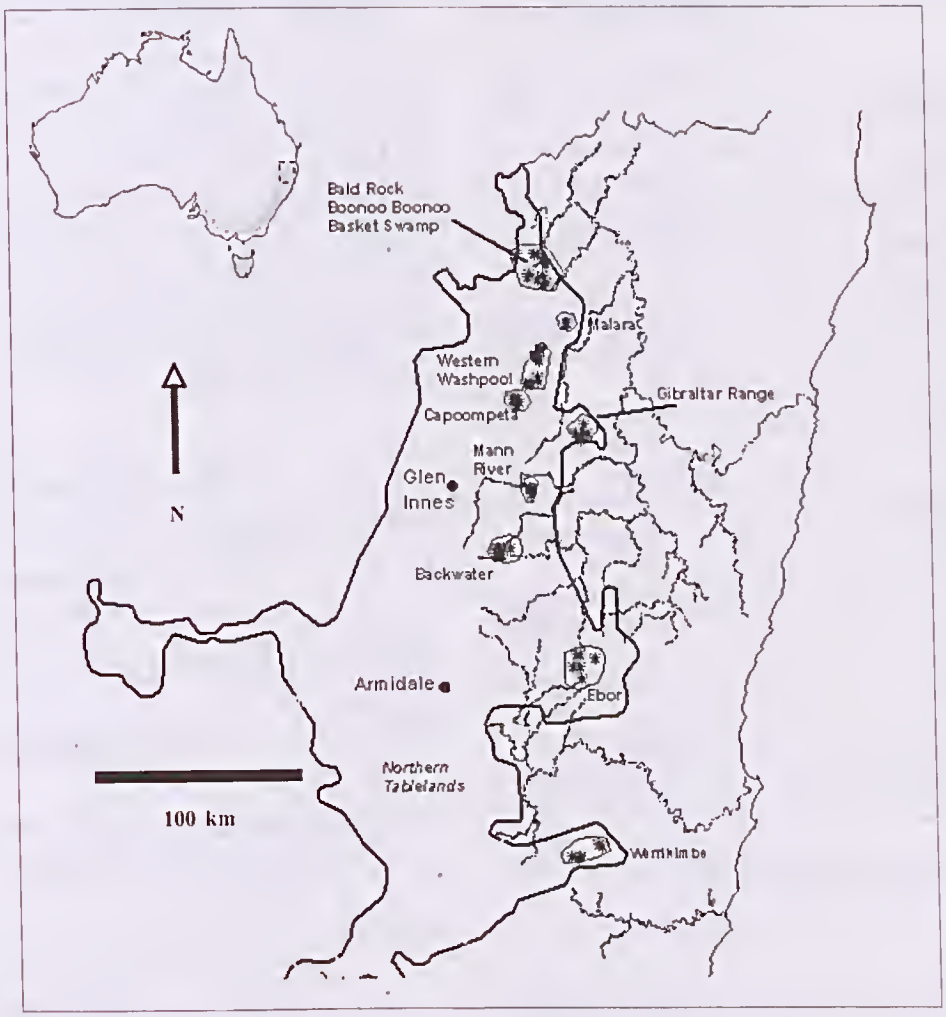


Fig. 1. Location of sampled montane bog areas in northern New England. Inset shows distribution of montane mires within Australia

sieberiana, Dianella revoluta, Dianella caerulea, Craspedia variabilis, Chrysocephalum apiculatum, Caladenia carnea, Brachyscome scapigera, Baloskion fimbriatum.

Occasional emergents: *Eucalyptus dalrympleana* subsp. *heptantha, Eucalyptus acaciiformis, Eucalyptus cameronii, Allocasuarina littoralis, Banksia integrifolia, Eucalyptus propinqua, Eucalyptus dorrigoensis.*

Introdueed taxa: *Axonopus affinis, Hypochaeris radicata, Setaria pumila, Centaurium erythraea, Prunella vulgaris, Hypochaeris glabra, Cirsium vulgare, Taraxacum officinale, Plantago lanceolata, Phalaris aquatica, Marrubium vulgare, Conyza albida.*

Rock type: granite and acid volcanies.

Distribution: found from north east of Tenterfield south to south-east of Glen Innes.

Reservation: Bald Roek NP, Boonoo Boonoo NP, Capoompeta NP, Western Washpool NP, Mann River NR.

Community 2: Baeckea ouissa – Leptospermum gregarium/Baumea articulata – Baloskiou steuocoleum

Shrubs: *Baeckea omissa, Leptospermum gregarium, Epacris microphylla, Hakea microcarpa, Callistemon pityoides, Callistemon pallidus, Banksia cunninghamii, Banksia spinulosa, Haka eriantha, Pultenaea villosa, Leptospermum trinervium, Leptospermum arachnoides, Persoonia oleoides, Hakea laevipes, Grevillea juniperina, Daviesia latifolia.*

Ground cover: *Baumea articulata, Baloskion stenocoleum, Gonocarpus micranthus, Themeda ausralis, Lomandra multiflora, Schoenus apogon, Lepidosperma limicola, Xyris operculata, Pteridium esculentum, Poa queenslandica, Pennisetum alopecuroides, Lepidosperma elatius, Goodenia bellidifolia, Geranium solanderi* subsp. *grande, Entolasia stricta, Cyperus gracilis, Stylidium graminifolium, Ranunculus lappaceus, Lycopodiella cernua, Imperata cylindrica, Drosera burmannii, Dianella longifolia, Utricularia dichotoma, Schoenus melanostachys, Rhynchospora brownii, Plantago varia, Persicaria decipiens, Lindsaea linearis, Lepidosperma laterale, Isolepis*

Table 1: Selected attributes of the seven defined montane bog communities in eastern flowing catchments of the northern New England.

Community	Number of sites	Mean species richness per 400 m² (range)	Total number of species	Number of exotic species	%Shrubs %Herbs %Trees	Altitude (metres)	Mean annual rainfall range (mm)
C1: *Epacris microphylla – Leptospermum arachnoides / Themeda australis – Gonocarpus micranthus*	10	30 (21–38)	144	12	18 81 1	990–1230	978–1074
C2: *Baeckea omissa – Leptospermum gregarium / Baumea articulata – Baloskion stenocoleum*	7	24 (16–37)	101	3	26 72 2	955–1060	872–1097
C3: *Baeckea omissa – Epacris microphylla / Lepidosperma limicola – Baloskion stenocoleum*	13	28 (19–45)	145	8	30 68 2	940–1250	915–1142
C4: *Baeckea omissa – Leptospermum gregarium / Baloskion fimbriatum – Lomandra longifolia*	5	42 (30–62)	119	6	20 72 8	1070–1225	882–956
C5: *Baeckea omissa – Leptospermum gregarium / Lepyrodia scariosa – Blandfordia grandiflora*	4	14 (13–15)	26	0	27 73 0	1150–1160	1136–1154
C6: *Epacris microphylla – Leptospermum arachnoides / Lepidosperma gunnii – Lepidosperma scariosa*	3	22–33 (28)	54	0	45 49 6	1050–1125	1138–1257
C7: *Baeckea omissa – Hakea microcarpa / Baloskion stenocoleum – Empodisma minus*	11	23 (18–35)	90	8	22 73 4	851–1372	1043–1715
C8: *Baeckea omissa – Epacris obtusifolia / Lepidosperma limicola – Xyris operculata*	8	22 (12–35)	69	1	38 63 0	920–1040	1210–1253

subtilissima, Isolepis nodosa, Haloragis heterophylla, Gleichenia dicarpa, Galnia sieberiana, Epilobium gunniana, Entolasia marginata, Drosera binata, Cyperus unioloides, Carex fascicularis, Blechnum penna-marina, Austrofestuca eriopoda.

Occasional emergents: *Eucalyptus dalrympleana* subsp. *heptantha, Eucalyptus radiata* subsp. *sejuncta, Eucalyptus camphora* subsp. *relicta, Eucalyptus pauciflora, Eucalyptus nova-anglica, Eucalytpus notabilis, Eucalyptus cameronii, Eucalytpus brunnea, Allocasuarina littoralis.*

Introduced taxa: *Axonopus affinis, Hainardia cylindrica, Cyperus eragrostis.*

Rock type: granite and metasediments.

Distribution: known from north-east of Tenterfield south to the Baekwater area.

Reservation: Basket Swamp NP, Warra NP, Western Washpool NP.

Community 3: Baeckea omissa – Epacris microphylla/ Lepidosperma limicola – Baloskion stenocoleum

Shrubs: *Baeckea omissa, Epacris microphylla, Callistemon pityoides, Leptospermum gregarium, Leptospermum arachnoides, Hakea microcarpa, Banksia cunninghamii, Boronia parviflora, Hibbertia acicularis, Pimelea linifolia, Callistemon citrinus, Epacris obtusifolia, Pultenaea pycnocephala, Pimelea glauca, Hibbertia riparia, Grevillea acanthifolia* subsp. *stenomera, Callistemon pallidus.*

Ground cover: *Lepidosperma limicola, Baloskion stenocoleum, Goodenia bellidifolia, Entolasia stricta, Xyris complanata, Gonocarpus micranthus, Themeda australis, Thelionema grande, Xyris operculata, Gymnoschoenus sphaerocephalus, Gleichenia dicarpa, Geranium solanderi* var. *grande, Austrostipa rudis, Lepyrodia anarthria, Hypericum gramineum, Rhynchospora browniі, Lycopodiella cernua, Lindsaea linearis, Baloskion fimbriatum, Thelionema caespitosum, Schoenus apogon, Ranunculus lappaceus, Patersonia glabrate, Lepidosperma gunnii, Haemodorum planifolium, Drosera binata, Deyeuxia imbricata, Craspedia variabilis, Utricularia dichotoma, Lomandra longifolia, Gaodenia hederacea, Galnia sieberiana, Eleocharis sphacelata, Cryptostylis subulata, Selaginella uliginosa, Schoenus melanostachys, Ptilothrix deusta, Hypericum japonicum, Hydrocotyle pedunculoris.*

Occasional emergents: *Eucalyptus pauciflora, Eucalyptus dalrympleana* subsp. *heptantha, Banksia integrifolia.*

Introduced taxa: *Andropogon virginicus, Prunella vulgaris, Phalaris aquatica, Dactylis glomerata, Conyza albida, Hypochaeris radicata, Hypochaeris glabra, Axonopus affinis.*

Rock type: granite and acid volcanic.

Distribution: found from north-east of Tenterfield to the Backwater area.

Reservation: Bald Rock NP, Boonoo Boonoo NP, Basket Swamp NP, Warra NP, Capoompeta NP, Mann River NR.

Community 4: Baeckea omissa – Leptospermum gregarium/Baloskion fimbriatum – Lomandra longifolia

Shrubs: *Baeckea omissa, Leptospermum gregarium, Hakea microcarpa, Epacris microphylla, Callistemon pityoides, Banksia cunninghamii, Lomatia fraseri, Petrophile canescens, Monotoca scoparia.*

Ground cover: *Baloskion fimbriatum, Lomandra longifolia, Goodenia bellidifolia, Viola hederacea, Patersonia fragilis, Lepyrodia anarthria, Helichrysum scorpioides, Gonocarpus micranthus, Geranium solanderi* var. *grande, Juncus vaginatus, Gratiola peruviana, Dichelachne inaequiglumis, Stylidium graminifolium, Scirpus polystachyus, Pteridium esculentum, Isachne globosa, Echinopogon caespitosus, Carex lobolepis, Schoenus apogon, Scaevola ramosissima, Poa sieberiana, Imperata cylindrica, Haloragis heterophylla, Craspedia variabilis, Austrodanthonia racemosa, Poranthera microphylla, Lythrum salicaria, Lepyrodia leptocaulis, Lepidosperma limicola, Hydrocotyle geraniifolia, Goodenia hederacea, Dichondra repens, Cyperus sphaeroideus, Carex inversa, Austrofestuca eriopoda.*

Occasional emergents: *Eucalyptus dalrympleana* subsp. *heptantha, Eucalyptus pauciflora, Eucalyptus camphora* subsp. *relicta, Banksia integrifolia, Acacia filicifolia, Eucalyptus acaciiformis, Eucalyptus caliginosa, Eucalyptus nova-anglica, Eucalyptus nobilis.*

Introduced taxa: *Hypochaeris radicata, Hypochaeris glabra, Centaurium erythraea, Prunella vulgaris, Juncus capitatus, Holcus lanatus.*

Rock type: granite.

Distribution: restricted to the Baekwater area, north-east of Guyra.

Reservation: Warra NP.

Community 5: Baeckea omissa – Leptospermum gregarium/Lepyrodia scariosa – Blandfordia grandiflora

Shrubs: *Baeckea omissa, Leptospermum gregarium, Callistemon pityoides, Banksia spinulosa, Epacris microphylla, Triplarina imbricata, Callistemon sieberi.*

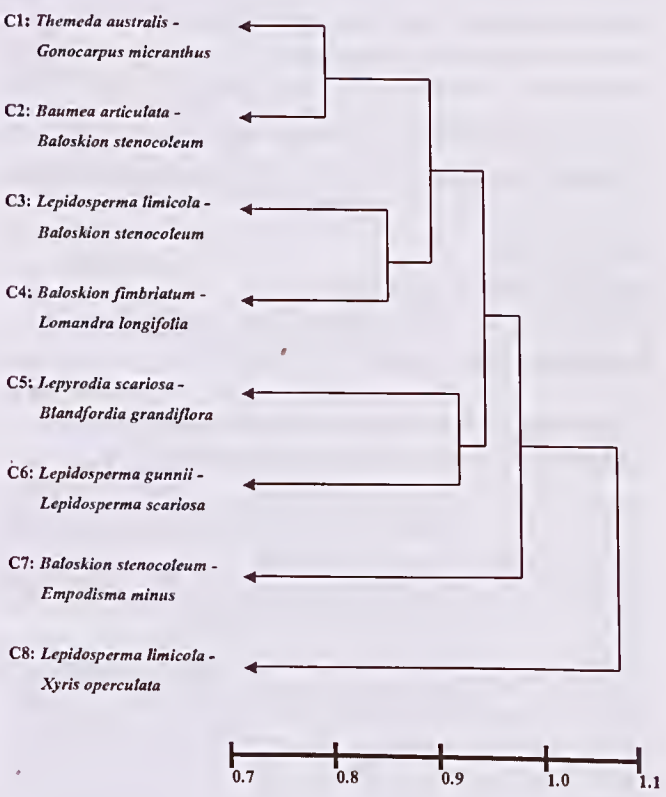

C1: Themeda australis - Gonocarpus micranthus
C2: Baumea articulata - Baloskion stenocoleum
C3: Lepidosperma limicola - Baloskion stenocoleum
C4: Baloskion fimbriatum - Lomandra longifolia
C5: Lepyrodia scariosa - Blandfordia grandiflora
C6: Lepidosperma gunnii - Lepidosperma scariosa
C7: Baloskion stenocoleum - Empodisma minus
C8: Lepidosperma limicola - Xyris operculata
0.7
0.8
0.9
1.0
1.1

Fig. 2. Summary dendrogram of full dataset of sites using Kulczynski association and flexible UPGMA fusion strategy. Community descriptors use herbaceous species names as they were more diagnostic than overstorey shrubs.

Ground cover: *Lepyrodia scariosa, Blandfordia grandiflora, Goodenia bellidifolia, Gonocarpus micranthus, Xyris complanata, Baloskion stenocoleum, Austrostipa scabra, Xanthorrhoea acaulis, Lepyrodia anarthria, Schoenus apogon, Lepidosperma tortuosum, Drasera peltata, Utricularia dichatoma, Gonacarpus areophilus, Entolasia stricta, Drosera spatulata, Drosera binata, Cynoglossum australe, Poa queenslandica.*

Occasional emergents: none apparent.

Introduced taxa: none apparent.

Rock type: granite.

Distribution: restricted to south-east of Tenterfield.

Reservation: Western Washpool NP.

Community 6: Epacris microphylla – Leptospermum arachnoides/Lepidosperma gunnii – Lepyrodia scariosa

Shrubs: *Epacris microphylla, Leptospermum arachnaides, Baeckea omissa, Cunesperma retusum, Dillwynia phylicaides, Petrophile canescens, Persoonia oleoides, Melichrus procumbens, Callistemon citrinus, Melichrus urceolatus, Leptaspermum novae-angliae, Banksia spinulosa, Pultenaea pycnacephala, Leptospermum minutifalium, Pimelea linifalia, Hakea laevipes* subsp. *graniticala, Callistemon viminalis, Boronia parviflora, Brachylana daphnoides* subsp. *glabrum.*

Ground cover: *Lepidosperma gunnii, Gaodenia bellidifolia, Aristida jerichoensis, Lepyradia scariasa, Dampiera stricta, Austrostipa pubescens, Entolasia stricta, Baloskion stenocoleum, Trachymene incisa, Selaginella uliginosa, Lepidaspermo limicola. Gonocarpus micranthus, Pteridium esculentum, Lindsaea linearis, Lepidosperma neesii, Hovea heterophylla, Drosera spatulata, Dianella caerulea, Bossiaea neo-anglica, Stylidium graminifolium, Schoenus melanostachys, Rhytidasporum diosmoides, Patersonia fragilis, Lomandra longifolia, Lepidosperma tortuosum, Haemadarum planifolium, Gleichenia dicarpa, Dianella longifolia, Austrostipa scabra.*

Occasional emergents: *Eucalyptus williamsiana, Eucalytpus radiata* subsp. *sejuncta, Eucalyptus dorrigoensis.*

Rock type: granite.

Introduced taxa: *Axonopus affinis.*

Distribution: from the Malara Plateau south to east of Deepwater.

Reservation: Western Washpool NP, Demon NR.

Community 7: Baeckea omissa – Hakea microcarpa/ Baloskion stenocoleum – Empodisma minus

Shrubs: *Baeckea omissa, Hakea microcarpa, Epacris microphylla, Leptospermum gregarium, Callistemon pityoides, Hibbertia acicularis, Epacris obtusifolia, Grevillea acanthifolia* var. *stenomera, Pultenaea villosa, Epacris breviflora, Boronia microphylla, Leptospermum navae-angliae, Charetrum candollei, Banksia cunninghamii.*

Ground cover: *Baloskion stenocoleum, Empodisma minus, Xyris complanata, Patersonia fragilis, Juncus subsecundus, Tetrarrhena turfosa, Isachne globosa, Deyeuxia gunniana, Lepidosperma limicola, Gleichenia dicarpa, Scaevala hookeri, Gymnoschoenus sphaerocephalus, Galium gaudichaudii, Ranunculus lappaceus, Lepyrodia anarthria, Hypericum japonicum, Geranium salanderi* var. *grande, Mitrasacme serpyllifolia, Lepyrodia scariosa, Juncus alexandri, Gonocarpus micranthus, Gahnia sieberiana, Austrostipa rudis, Hydrocotyle peduncularis, Goodenia bellidifolia, Euchiton sphaericus, Viola hederacea, Poa sieberiana, Dichondra repens, Austrodanthonia monticola, Scirpus polystachyus, Lomandra longifolia, Lepidosperma gunnii, Isotoma fluviatilis, Isolepis Habra, Epilobium billardierianum, Deyeuxia parviseta, Thelionema grande, Selaginella uliginosa, Plantago debilis, Pennisetum alopecuroides, Myriophyllum variifolium, Juncus continuus, Ganocarpus oreophilus, Eriacaulon scariosum, Carex gaudichaudii, Carex appressa, Blechnum nudum, Baumea rubiginosa.*

Occasional emergents: *Eucalyptus acaciiformis. Eucalyptus pauciflarus, Eucalyptus dalrympleana* subsp. *heptantha.*

Introduced taxa: *Phalaris aquatica, Callitriche stagnalis, Holcus lanatus, Anthaxanthum odoratum, Rubus fruticasus, Juncus capitatus, Conyza albida, Cirsium vulgare.*

Rock type: granite and basalt.

Distribution: restricted to the southern locations within the study area from Ebor south to east of Waleha.

Reservation: Cathedral Rocks NP, Werrikimbe NP

Community 8: *Baeckea omissa – Epacris obtusifolia/ Lepidosperma limicola – Xyris operculata*

Shrubs: *Baeckea omissa, Epacris obtusifolia, Leptospermum arachnoides, Banksia spinulosa, Epacris microphylla, Hibbertia rufa, Boronia polygalifolia, Prostanthera saxicola, Logania pusilla, Hakea laevipes* subsp. *graniticala, Callistemon citrinus, Pultenaea villosa, Notelaea linearis, Grevillea acanthifolia* var. *stenomera, Boronia parviflora, Bauera rubioides.*

Ground cover: *Lepidosperma limicola, Xyris operculata, Lepyradia scariosa, Drosera binata, Drosera spatulata, Baloskion fimbriatum, Amphipogon strictus, Thelionema caespitosum, Gonocarpus micranthus, Caustis flexuosa, Goodenia bellidifolia, Entolasia stricta, Tricastularia pauciflora, Schoenus brevifolius, Blandfordia grandiflora, Geranium solanderi* var. *solanderi, Selaginella uliginasa, Patersania fragilis, Eragrastis elongata, Tetrarrhena juncea, Gymnaschoenus sphaerocephalus, Trachymene incisa, Lycopodiella lateralis, Lindsaea linearis, Hypericum gramineum, Rhytidasporum procumbens, Panicum paludasum, Drosera peltata, Deyeuxia gunniana, Baloskion stenacoleum, Austrostipa pubescens, Austrodanthonia induta.*

Occasional emergents: none apparent.

Introduced taxa: *Axonopus affinis.*

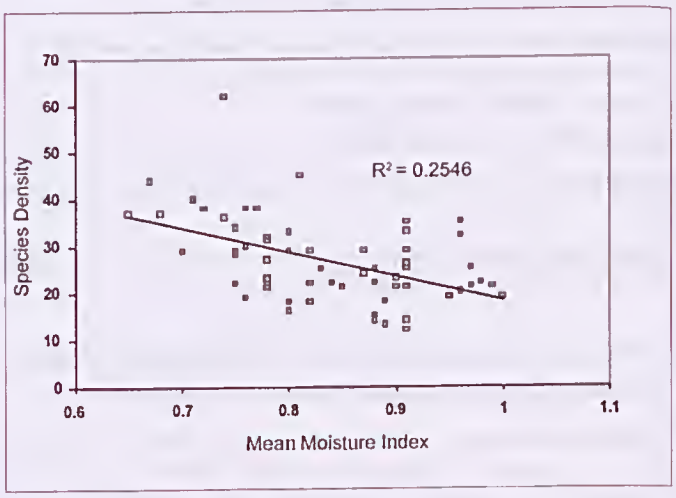


Fig. 3. The affect of annual mean moisture index on speeies density. Mean moisture index aeeounts for nearly 26% of the variation shown in the number of speeies per plot.

Distribution: from the Malara Plateau east of Tenterfield south to Carrai east of Walcha.

Reservation: Demon NR, Gibraltar Range NP. Carrai NP and SCA.

Discussion

Montane bogs in northern New England, with 438 taxa (including 28 exotic species), have a large species pool, compared to other montane bogs in Australia. This compares to 269 (19 exotics) in Victoria (Whinam et al. 2002) and 171 in Tasmania (Whinam et al. 2001). The dominant life-form types across all communities were herbs, reflected in many sedge genera being rich in species (*Carex, Isolepis, Lepidosperma*). It has been suggested (Keith 2004; Williams & Clarke 2006), that groundlayer species in such bog systems are dominated by the monocotyledon families Cyperaceae, Juncaceae and Restionaceae, and the shrub layer by Epacridaceae, Fabaceae and Myrtaceae, and our study shows some correlation with this list, but some exceptions. We found, in order of importance, that Poaceae, Cyperaceae and Asteraceae were the most prominent herbaceous families with Myrtaceae, Fabaceae and Proteaceae being the more important shrub families. Pemberton et al. (2005) list five species-rich families in Tasmanian bogs, four of which were also found in our list of the richest families, the exception being Restionaceae, which was of less importance in this study.

Surprisingly *Eucalyptus* was found to be the richest genus (19 species), even though in most situations none were present within bog communities. Occasionally however, a few eucalypts occurred as single or scattered individuals. Emergent eucalypts can be considered to fall into three broad types, those that are adapted to montane bog environments, those that occur in marginal montane bog environments and those that have opportunistically-germinated due to local or temporal safe sites. Only one eucalypt taxon, *Eucalyptus camphora* subsp. *relicta*, could be considered to be a montane bog specialist within the study area. *Eucalyptus dalrympleana* subsp. *heptantha, Eucalyptus acaciiformis, Eucalyptus nova-anglica, Eucalyptus panciflora* and *Eucalyptus radiata* subsp. *sejuncta* are taxa that are often found around the margins of montane bogs and may periodically encroach and then die back due to fluctuations in the watertable. The other eucalypt taxa recorded are opportunists that may be found around the margins where the watertable is lower, on occasional isolated 'humps' of mounded soil, on fugitive underlying rock outcrops or temporarily within the bogs when reduced rainfall initiates a drop in watertables. This same phenomenon may also account for the high richness in the Poaceae.

Shrubs on average accounted for 26% (110 taxa) of the total flora, though only 26% of these (29 taxa) could be called montane bog specialists. The percentage of shrubs was less than for Tasmanian bogs (32%) (Pemberton et al. 2005). Five of the New England montane bog specialist shrubs (*Baeckea omissa, Leptospermum gregarium, Leptospermum arachnoides, Hakea microcarpa, Epacris microphylla*) were widespread and dominated nearly all of the communities described but although important as a dominant structural life form (in the sense that they form the tallest stratum), shrubs are non-diagnostic of composition within montane bog communities of this region. The herbaceous layer was far richer and more useful as a diagnostic tool for delineating assemblages within the northern New England. The shrubs are highly diagnostic for cross comparison purposes over larger extents (i.e. across more regions).

Within the study area mean moisture index was found to be a highly predictive variable accounting for 26% of the variation in the number of species found in each plot, providing evidence that this is a common correlative feature of bog communities (Jarman et al. 1988; Keith 2004; Whinam & Hope 2005).

This investigation builds on work of Whinam and Chilcott (2002) who sampled *Sphagnum*-dominated communities in NSW as far north as Backwater. From our observations the incidence of *Sphagnum cristatum* ranged from well-developed hummock-hollow micro-topography (e.g. Werrikimbe, Cathedral Rocks, New England National Park, Western Washpool and Malara), through occasional occurrence of *Sphagnum* in the wettest parts of sites, to total absence in dry or heavily fire-impacted localities. At the community level *Sphagnum* was present and prominent in all the assemblages described here, and was also a feature of the communities in the most northerly sites.

Though depth of peat was not formally measured, observations suggest that peat depth varied considerably within and between communities, but more consistently was less well-developed to the north and west. In some sites the peat layer was almost absent. Possible explanations for variation in peat depth include lower peat accumulation due to reduced rainfall, increased evapotranspiration, the composition of the flora, increased temperature, or peat destruction such as through slippage and fire (Whinam & Chilcott 2002; Hope & Kershaw 2005; Whinam & Hope 2005). The origin of peat in the study area is not known but is likely to be largely based on cyperaceous litter (Agnew et al. 1993; Whinam & Chilcott 2002; Clarkson & Buxton 2005).

In previous analyses of *Sphagnum*-dominated vegetation (Whinam & Chilcott 2002; Whinam et al. 2002) vegetation assemblages have been largely related to geographic location and altitude. Clarke et al. (2000) suggested that rock type was also a significant factor in differentiating montane bog vegetation in New England National Park. However in this current investigation most communities were shared across many sample areas, and neither locality, nor rock type appears to be significant in differentiating montane bog communities in our analyses. Some authors have suggested distinctive banding within New England bog systems (Millington 1954; Williams & Clarke 1997; Williams & Clarke 2006) but our experience is that, except where extreme gradients exist,

banding is largely indistinct. Patterning is more an exception, as mosaics are formed by temporal changes in groundwater and flooding levels, and the occurrence and frequency of fire. Where extreme gradients occur, such as along permanent water channels, specialist shrub species that are usually not found in the general bog matrix, (e.g. *Callistemon pungens, Callistemon pallidus, Callistemon viminalis, Leptospermum polygalifolium*) may occur.

Floristic affinities

Previous floristic investigations have involved numeric comparisons between local montane bogs and other vegetation communities within the local landscape. In all instances montane bog vegetation has been delineated as a separate and distinct vegetation assemblage, but showing a great affinity with other heathy systems, such as rock outcrops, heathy forests, woodlands and heathy rocky riparian environments (Binns 1992; Binns 1995; Chapman & Binns 1995; Hunter 1998; Hunter 1999; Hunter et al. 1999; Benson & Ashby 2000; Clarke et al. 2000; Hunter 2000; Sheringham & Hunter 2002; Hunter 2004ab; Hunter 2005b). This affinity is initially somewhat surprising as shrubs account for only 26% of all species in montane bogs, and the most common dominant shrubs (*Baeckea omissa, Epacris microphylla, Leptospermum gregarium, Leptospermum arachnoides, Callistemon pityoides* and *Hakea microcarpa*) are restricted to bogs. In addition species of the dominant herbaceous layer are highly restricted to bog environments. However, as has been found with the highly endemic rock outcrop floras of the same region, the highly specialised montane bog endemics may be abundant, but are low in richness (Hunter 2001; Hunter 2003). The majority of taxa, especially within the herbaceous flora, occur infrequently, are not dominants, and are generally ubiquitous in nearby communities.

The shrub flora however is generally shared more specifically with other heathy assemblages, and some taxa that are primarily rock outcrop taxa (Hunter & Clarke 1998; Hunter 2002), e.g. *Leptospermum novae-angliae, Kunzea bracteolata, Eucalyptus scias* subsp. *apoda* and *Thelionema grande,* will also occur within montane bogs, but within no other communities. Both these environments share low pH (Hunter 2001; Whinam & Chilcott 2002) and at least physiological drought conditions.

Conservation issues

Benson & Ashby (2000) found that for the Guyra 1: 100 000 Map Sheet area, 80% of the original extent of montane bogs were still extant and generally in good condition, though poorly-represented in conservation reserves. The Guyra map sheet area was thought to contain 370 ha of montane bogs of which 15 ha were in reserves. Based on current mapping technology (using on ground surveying and verification), it is estimated that potentially 2700 ha of bog communities are incorporated in the reserve network (Hunter 1998; Hunter 1999; Hunter et al. 1999; Benson & Ashby 2000; Clarke et al. 2000; Hunter 2000; Sheringham & Hunter 2002; Hunter 2004ab; Hunter 2005b) and that at least 10 000 ha in total potentially exist in northern New England. If wetlands other than bogs, such as fens and lagoons were to be included this figure would be much enlarged. This is far in excess of the total swamp/wetlands area (1970 ha) thought to exist on the northern tablelands and north western slopes by Wall (2000). This large discrepancy is difficult to explain without close inspection of the data used by Wall (2000) in modelling. However, when comparing previous mapping products, areas such as wetlands (and low dry heathlands) have often been misinterpreted, from remote sensing alone, as cleared lands (pers. obs.). Previous modelling of vegetation assemblages on the Northern Tablelands have often emphasised forest associations, due to disputes over forestry, and this emphasis may also account for the low number of hectares previously predicted for wetlands on the Tablelands. These suggestions are speculative; the main reason for our increase in the amount of wetlands on the tablelands is likely to be purely due to an increased on-ground effort.

Whinam and Chilcott (2002) found that *Sphagnum*-dominated bog communities, even within conservation reserves, were in poor condition due to past land use practices. Much of our surveying occurred within conservation reserves and where the bogs were considered to be in good condition. However threatening processes such as over-grazing, frequent fire and nutrient enrichment were evident in many locations outside reserves. Even within reserves some locations appeared to have been burnt too frequently. However, some extensive, relatively intact bogs such as Tin Swamp (east of Tenterfield), along road reserves throughout the region and above the northern boundary of Butterleaf National Park also exist outside the reserve network.

Species associated with higher nutrient wetland systems (e.g. *Phragmites australis, Scirpus polystachyus* and *Carex gaudichaudii*) have been encroaching into bogs in and near Cathedral Rocks and New England National Parks within the last ten years (*pers. obs.*). Some bogs were affected by *Phytophthora*, particularly those in the Werrikimbe area. Drought also was noted to have affected the shrub layer causing much dieback and death in the worst affected areas. Montane bog systems have developed due to particular combinations of temperature and rainfall, we concur with others who consider them highly susceptible to future climate change (Whinam & Chilcott 2002).

Despite the shrub species richness being comparatively low in bogs of the region, shrubs are over-represented in those taxa considered to be rare and threatened. Of the 20 rare taxa found associated with New England Bioregion montane bogs, 15 were shrubs and two were trees. Of the three taxa listed on the NSW *Threatened Species Conservation Act* (1995), two are endangered (*Eucalyptus camphora* subsp. *relicta, Triplarina imbricata*) and one vulnerable (*Grevillea juniperina* subsp. *allojohnsonii*). 17 other species were listed on the RoTAP list

as either vulnerable (*Baeckea gunniana*), rare (*Callistemon pungens, Thelionema grande, Eucalyptus dorrigoensis, Pultenaea pycnocephala, Acacia barringtonensis, Carex capillacea, Persoonia daphnoides, Kunzea bracteolata, Grevillea acanthifolia* subsp. *stenomera, Melaleuca tortifolia, Grevillea acerata, Acacia orites, Acacia floydii, Persoonia procumbens* and *Aciantlius apprimus*) or as poorly known (*Eucalyptus scias* subsp. *apoda*) (Briggs & Leigh 1996; Richards & Hunter 1997; Copeland & Hunter 1999).

This study has highlighted the significance of New England montane bogs. These systems are some of the richest within Australia with a high number of rare and restricted taxa. They are vulnerable to both present landuse practices and future changes in climate, and are restricted in area, thus needing further conservation initiatives. Despite the apparent similarity in structure and composition of the overstorey shrubs these communities are best delineated by the composition of their herbaceous substratum. Further work is required to interpret the complexities associated with the dynamics of these systems.

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Appendix: Floristic composition of montane bogs of east flowing catchments of northern New England.

Taxa present in each of the eight communities. Some taxa were found in previous surveys or opportunistically (Op). Some orchid identifications may be identified in a broad taxonomic sense (*sens. lat.*). Nomenclature follows that of Harden (1990–1993) except where recent changes have occurred (PlantNET 2006).* Indicates exotic species.

1 = *Epacris microphylla – Leptospermum arachnoides/ Themeda australis – Gonocarpus micranthus*,

2 = *Baeckea omissa – Leptospermum gregarium/Baumea articulata – Baloskion stenocoleum*,

3 = *Baeckea omissa – Epacris microphylla/Lepidosperma limicola – Baloskion stenocoleum*,

4 = *Baeckea omissa – Leptospermum gregarium/Baloskion fimbriatum – Lomandra longifolia*,

5 = *Baeckea omissa – Leptospermum gregarium/Lepyrodia scariosa – Blandfordia grandiflora*,

6 = *Epacris microphylla – Leptospermum arachnoides/ Lepidosperma gunnii – Lepidosperma scariosa*,

7 = *Baeckea omissa – Hakea microcarpa/Baloskion stenocoleum – Empodisma minus*,

8 = *Baeckea omissa – Epacris obtusifolia/Lepidosperma limicola – Xyris operculata*.

	1	2	3	4	5	6	7	8	Op
Anthericaceae									
Arthropodium milleflorum				4					
Caesia parviflora									Op
Dichopogon fimbriatus				4					
Thysanotus tuberosus	1								
Tricoryne elatior	1		3	4					
Apiaceae									
Centella asiatica	1			4					
Hydrocotyle geraniifolia	1			4			7		
Hydrocotyle laxiflora									
Hydrocotyle pedunculoris	1		3	4			7		
Platysace ericoides									Op
Trachymene incisa subsp. *incisa*			3	4		6		8	
Araceae									
Gymnostachys anceps			3						
Aspleniaceae									
Asplenium flavellifolium							7		
Asteraceae									
Brachyscome angustifolia var. *angustifolia*	1								
Brachyscome angustifolia var. *heterophylla*									Op
Brachyscome microcarpa	1								
Brachyscome nova-anglica			3	4					
Brachyscome scapigera	1								
Brachyscome spathulata									Op
Brachyscome tenuiscapa var. *pubescens*				4					
Chrysocephalum apiculatum	1		3						
Chrysocephalum semipapposum		2	3	4					
**Cirsium vulgare*	1						7		
**Conyza albida*	1		3				7		
**Conyza bonariensis*									Op
Craspedia canens	1		3						
Craspedia variabilis	1		3	4					
Euchiton gymnocephalus	1								
Euchiton sphaericus	1			4			7		
Helichrysum boormanii			3						
Helichrysum rutidolepis									Op
Helichrysum scorpioides	1		3	4					
**Hypochaeris glabra*	1		3	4					
**Hypochaeris radicata*	1		3	4					
Microseris lanceolata	1								
Ozothamnus diosmifolius	1								
Podolepis jaceoides		2							
Rhodanthe anthemoides									Op
Senecio biserratus	1								
Senecio diaschides				4					
Senecio hispidulus var. *hispidulus*			3						
Senecio prenanthoides									Op
**Sonchus oleraceus*									Op
**Taraxacum officinale*	1								
Xerochrysum bracteatum									Op
Baueraceae									
Bauera rubioides var. *rubioides*								8	
Blandfordiaceae									
Blandfordia grandiflora	1				5				
Blechnaceae									
Blechnum nudum							7		
Blechnum penna-marina subsp. *alpina*		2							
Blechnum wattsii				4					
Boraginaceae									
Cynoglossum australe					5				
Myosotis australis									Op
Callitrichaceae									
**Callitriche stagnalis*							7		
Campanulaceae									
Wahlenbergia ceracea	1	2							
Wahlenbergia communis				4					
Wahlenbergia stricta subsp. *stricta*									Op

Caryophyllaceae								
Cerastium vulgare								Op
Stellaria angustifolia				4				
Casuarinaceae								
Allocasuarina littoralis	1	2						
Allocasuarina rigida subsp. *rigida*						7		
Clusiaceae								
Hypericum gramineum	1	2	3	4		7	8	
Hypericum japonicum	1		3			7		
Colchicaceae								
Wurmbea dioica subsp. *dioica*	1							
Convolvulaceae								
Dichondra repens	1			4		7		
Cyperaceae								
Baumea articulata		2						
Baumea gunnii								Op
Baumea rubiginosa						7		
Bulbostylis densa	1							
Carex appressa						7		
Carex capillacea								Op
Carex fascicularis		2						
Carex gaudichaudiana						7		
Carex incomitata								Op
Carex inversa				4				
Carex lobolepis				4				
Carex longebrachiata	1							
Caustis flexuosa			3				8	
**Cyperus eragrostis*		2						
Cyperus gracilis	1	2						
Cyperus sanguinolentus						7		
Cyperus sphaeroideus				4				
Cyperus unioloides		2						
Eleocharis dietrichiana		2						
Eleocharis sphacelata			3					
Fimbristylis dichotoma		2						
Gahnia aspera	1							
Gahnia sieberiana	1	2	3			7		
Gymnoschoenus sphaerocephalus			3			7	8	
Isolepis cernua		2						
Isolepis crassiuscula								Op
Isolepis habra						7		
Isolepis hookeriana				4				
Isolepis inundata								Op
Isolepis nodosa		2	3					
Isolepis subtilissima		2						
Lepidosperma elatius	1	2						
Lepidosperma filiforme	1							
Lepidosperma gunnii			3		6	7		
Lepidosperma laterale		2	3					
Lepidosperma limicola	1	2	3	4	6	7	8	
Lepidosperma neesii	1		3			6		
Lepidosperma tortuosum			3		5	6		8
Philotheca deusta	1		3					
Rhynchospora brownii	1	2	3				7	
Schoenus apogon	1	2	3	4	5			
Schoenus brevifolius								8
Schoenus melanostachys	1	2	3			6		
Schoenus turbinatus								8
Scirpus polystachyus				4			7	
Tricostularia pauciflora								8
Dennstaedtiaceae								
Pteridium esculentum	1	2		4		6		8
Dilleniaceae								
Hibbertia acicularis			3				7	
Hibbertia linearis								Op
Hibbertia pedunculata			3					
Hibbertia riparia	1		3					
Hibbertia rufa								8
Droseraceae								
Drosera binata		2	3	4	5			8
Drosera burmannii	1	2	3	4				
Drosera peltata				4	5			8
Drosera spatulata	1	2	3		5	6		8
Epacridaceae								
Brachyloma daphnoides subsp. *glabrum*						6		8
Epacris breviflora							7	
Epacris microphylla var. *microphylla*	1	2	3	4	5	6	7	8
Epacris obtusifolia			3				7	8
Epacris pulchella			3					
Leucopogon lanceolatus var. *lanceolatus*			3					
Melichrus procumbens				4		6		
Melichrus urceolatus						6		
Monotoca scoparia		2	3	4				
Sprengelia incarnata								Op
Trochocarpa laurina								Op
Eriocaulaceae								
Eriocaulon scariosum				4			7	
Euphorbiaceae								
Poranthera microphylla		2		4				
Fabaceae								
Acacia barringtonensis								8
Acacia filicifolia				4				
Acacia floydii								
Acacia melanoxylon								Op
Acacia ulicifolia							7	
Aotus subglauca var. *subglauca*			3	4				
Bossiaea neo-anglica						6		
Bossiaea scortechinii		2						Op

Daviesia latifolia	2								
Daviesia nova-anglica		3							
Daviesia ulicifolia						7			
Desmodium varians			4						
Dillwynia phylicoides		3	4		6				
Dillwynia retorta			4						
Dillwynia sericea									Op
Dillwynia sieberi			4						
Glycine clandestina			4						
Glycine sp. A			4						
Gompholobium inconspicuum									Op
Hovea heterophylla					6				
Lotus uliginosus									Op
Mirbelia rubifolia									Op
Mirbelia speciosa subsp. *speciosa*							8		
Phyllota phylicoides									Op
Pultenaea altissima		3							
Pultenaea dentata									Op
Pultenaea myrtoides									Op
Pultenaea pycnocephala		3			6				
Pultenaea retusa		3							
Pultenaea villosa	2	3				7	8		
Sphaerolobium minus									Op
Sphaerolobium vimineum		3					8		
Trifolium repens									Op
Gentianaceae									
**Centaurium erythraea*	1			4					
Geraniaceae									
Geranium neglectum									Op
Geranium potentilloides var. *potentilloides*									Op
Geranium solanderi var. *grande*	1	2	3	4			7		
Geranium solanderi var. *solanderi*				4				8	
Gleicheniaceae									
Gleichenia dicarpa	1	2	3			6	7		
Goodeniaceae									
Dampiera stricta						6	7	8	
Goodenia bellidifolia subsp. *bellidifolia*	1	2	3	4	5	6	7	8	
Goodenia hederacea subsp. *hederacea*		2	3	4					
Scaevola hookeri							7		
Scaevola ramosissima				4					
Velleia montana									Op
Haemodoraceae									
Haemodorum planifolium	1		3			6			
Haloragaceae									
Gonocarpus humilis			3						
Gonocarpus micranthus	1	2	3	4	5	6	7	8	
Gonocarpus oreophilus		2			5		7		
Gonocarpus tetragynus	1	2	3	4		6	7	8	
Gonocarpus teucrioides	1		3	4					
Haloragis heterophylla		2		4					
Myriophyllum pedunculatum			3						
Myriophyllum variifolium							7		
Hypoxidaceae									
Hypoxis exilis	1								
Hypoxis hygrometrica var. *splendida*									Op
Iridaceae									
Patersonia fragilis	1		3	4		6	7	8	
Patersonia glabrata			3						
Patersonia sericea	1		3						
Juncaceae									
Juncus alexandri	1						7		
**Juncus capitatus*				4			7		
Juncus continuus		2	3				7		
Juncus fimus	1		3						
Juncus pauciflorus	1								
Juncus ochrocoleus		2	3	4	5	6	7	8	
Juncus phaeanthus							7		
Juncus planifolius									Op
Juncus prismatocarpus							7		
Juncus remotiflorus		2	3						
Juncus subsecundus				4			7		
Juncus usitatus		2							
Juncus vaginatus				4					
Luzula densiflora									Op
Luzula flaccida				4					
Lamiaceae									
Ajuga australis			3						
**Marrubium vulgare*	1								
Prostanthera saxicola								8	
Prostanthera scutellarioides									Op
**Prunella vulgaris*	1		3	4					
Lauraceae									
Cassytha glabella								8	
Lentibulariaceae									
Utricularia dichotoma	1	2	3	4	5			8	
Liliaceae									
Blandfordia grandiflora								8	
Lindsaeaceae									
Lindsaea linearis	1	2	3			6		8	
Lobeliaceae									
Isotoma fluviatilis							7		
Pratia pedunculata									Op
Pratia purpurascens	1								
Loganiaceae									
Logania pusilla								8	
Mitrasacme serpyllifolia							7		

Lomandraceae									
Lomandra elongata									Op
Lomandra filiformis	1								
Lomandra longifolia	1	2	3	4		6	7		
Lomandra multiflora subsp. *multiflora*	1	2	3			6			
Lycopodiaceae									
Lycopodiella cernua		2	3						
Lycopodiella lateralis								8	
Lycopodium deuterodensum									Op
Lythraceae									
Lythrum salicaria				4					
Menyanthaceae									
Nymphoides geminata			3						
Myrtaceae									
Baeckea gunniana									Op
Baeckea omissa	1	2	3	4	5	6	7	8	
Baeckea utilis									Op
Callistemon citrinus		2	3			6		8	
Callistemon pallidus		2	3	4					
Callistemon pityoides	1	2	3	4	5		7		
Callistemon pungens							7		
Callistemon sieberi	1		3		5				
Callistemon viminalis						6			
Eucalyptus acaciiformis	1			4			7		
Eucalyptus brunnea	1	2							
Eucalyptus caliginosa				4					
Eucalyptus cameronii	1	2							
Eucalyptus campanulata			3						
Eucalyptus camphora subsp. *relicta*		2		4					
Eucalyptus dalrympleana subsp. *heptantha*	1	2	3	4			7		
Eucolyptus dorrigoensis	1					6			
Eucalyptus ligustrina									Op
Eucalyptus nitens									Op
Eucalyptus nobilis				4					
Eucalyptus notabilis		2							
Eucalyptus nova-anglica		2		4					
Eucalyptus obliqua									Op
Eucalyptus pauciflora	1	2	3	4			7		
Eucalyptus propinqua	1								
Eucalyptus radiata subsp. *sejuncta*		2				6			
Eucalyptus scias subsp. *apoda*									
Eucalyptus williamsiana						6			
Kunzea bracteolata									Op
Leptospermum arachnoides	1	2	3			6		8	
Leptospermum brevipes		2							
Leptospermum gregarium	1	2	3	4	5		7		
Leptospermum minutifolium	1		3			6		8	
Leptospermum novae-angliae						6	7		
Leptospermum polygalifolium subsp. *montanum*									Op
Leptospermum polygalifolium subsp. *transmontanum*			3	4					
Leptospermum trinervium		2							
Melaleuca tortifolia									Op
Triplarina imbricata		2			5				
Oleaceae									
Notelaea linearis								8	
Onagraceae									
Epilobium billardierianum	1						7		
Epilobium gunnianum		2		4					
Epilobium hirtigerum									Op
Orchidaceae									
Acianthus fornicatus									Op
Acianthus pusillus			3						
Caladenia carnea	1								
Calochilus robertsonii			3						
Chiloglottis diphylla								8	
Chiloglottis pluricallata									Op
Cryptostylis subulata			3						
Microtis unifolia		2							
Orthoceras strictum								8	
Pterostylis cycnocephala	1								
Pterostylis furcata									Op
Pterostylis parviflora									Op
Spiranthes sinensis subsp. *australis*	1		3						
Thelymitra ixioides var. *ixioides*									Op
Thelymitra pauciflora	1								
Oxalidaceae									
Oxalis perennans	1								
Philydraceae									
Philydrum lanuginosum			3						
Phormiaceae									
Dianella caerulea	1			4		6			
Dianella longifolia		2				6			
Dianella revoluta var. *revoluta*	1			4					
Thelionema caespitosum	1		3	4				8	
Thelionema grande		2	3	4			7	8	
Pittosporaceae									
Billardiera scandens var. *scandens*		2							
Rhytidosporum diosmoides						6			
Rhytidosporum procumbens								8	
Plantaginaceae									
Plantago debilis							7		
**Plantago lanceolata*	1								
Plantago varia		2							

| | | |

Ranunculaceae									
Ranunculus lappaceus	1	2	3				7		
Restionaceae									
Baloskion fimbriatum	1	2	3	4				8	
Baloskion stenocoleum	1	2	3		5	6	7	8	
Empodisma minus		2	3				7		
Lepyrodia anarthria			3	4	5		7	8	
Lepyrodia leptocaulis				4					
Lepyrodia scariosa	1	2			5	6	7	8	
Rosaceae									
Acaena novae-zelandiae				4					
Acaena ovina									Op
**Rubus fruticosus*							7		
Rubus parvifolius		2		4					
Rubiaceae									
Asperula gunnii									Op
Coprosma quadrifida									Op
Galium gaudichaudii		2					7		
Galium migrans				4					
Nertera granadensis							7		
Opercularia hispida				4					
Rutaceae									
Boronia anethifolia			3						
Boronia microphylla			3				7		
Boronia parviflora	1		3			6		8	
Boronia polygalifolia			3					8	
Crowea exalata subsp. *exalata*	1								
Santalaceae									
Choretrum candollei							7		
Choretrum paniflorum									Op
Schizaeaceae									
Schizaea bifida	1								
Scrophulariaceae									
Euphrasia collina subsp. *paludosa*									Op
Gratiola peruviana	1			4					
Limosella australis									Op
Veronica calycina	1								
Veronica plebeia				4					
Selaginaceae									
Selaginella uliginosa	1		3			6	7	8	
Smilaceae									
Smilax australis									Op
Solanaceae									
Solanum nigrum									Op

Stylidiaceae									
Stylidium graminifolium	1	2	3	4			6	7	
Thymelaeaceae									
Pimelea glauca			3						
Pimelea linifolia	1		3				6		
Pimelea linifolia subsp. *linifolia*			3	4					
Pimelea strigosa	1								
Violaceae									
Hybanthus monopetalus									8
Viola betonicifolia	1		3						
Viola caleyana									Op
Viola hederacea	1		3	4				7	
Xanthorrhoeaceae									
Xanthorrhoea acanlis	1	2				5			
Xanthorrhoea glauca subsp. *glauca*			3						
Xanthorrhoea johnsonii									Op
Xanthorrhoea macronema	1		3						
Xyridaceae									
Xyris complanata	1		3	4	5			7	
Xyris gracilis subsp. *gracilis*									Op
Xyris operculata	1	2	3						8

Wallum on the Nabiac Pleistocene barriers, lower North Coast of New South Wales

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Abstract: Wallum is widespread on coastal dunefields, beach ridge plains and associated sandy flats in northern NSW and southern Queensland. These sand masses contain large aquifers, and the wallum ecosystem is considered to be generally groundwater-dependent.

This study describes the floristic composition and environmental relations of wallum on a Pleistocene barrier system at Nabiac (32° 09'S 152° 26'E), on the lower North Coast of NSW. Despite their minimal elevation and degraded relief, the Nabiac barriers maintain floristic patterns related to topography and hence groundwater relations. Comparative analyses identified the Nabiae wallum as representative of the ecosystem throughout large parts of its range in eastern Australia. The Nabiac wallum and nearby estuarine and alluvial vegetation supports species and communities of conservation significanec.

A borefield is proposed for development on the Nabiac barriers, thereby providing a valuable opportunity for researeh into mechanisms of groundwater utilisation by the wallum eeosystem.

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Introduction

Wallum is the regionally distinct vegetation on eoastal dunefields, beach ridge plains and sandy backbarrier flats in subtropical northern NSW and southern Queensland (Griffith et al. 2003). These sand masses are concentrated between Neweastle (33°S) and the Shoalwater Bay region (22°S) near Rockhampton, with scattered oecurrences further north and south (Thompson 1983). Wallum structural formations (after Walker & Hopkins 1984) include forest and woodland, mallee forest and woodland, shrubland, heathland and sedgeland.

Australia is reliant upon groundwater to satisfy domestic, industrial and agricultural requirements (e.g. Groom et al. 2001, Murray et al. 2006, NSW Government 1997). This reliance includes extraetion from sand mass aquifers supporting wallum (Davis 2000, NSW National Parks & Wildlife Service 1998), and also from similar aquifers supporting kwongan (sandplain) vegetation in south-western Australia (Dodd et al. 1984, Froend & Drake 2006).

MidCoast Water, a County Council established in 1997, is responsible for water supply to the Greater Taree and Great Lakes local government areas of NSW in the lower North Coast botanieal subdivision (after Anderson 1961). Water quality in the existing Manning District Water Supply Scheme, which pumps from the Manning River into a storage reservoir, is becoming increasingly diffieult to manage, especially during summer with the incidence of algal blooms. MidCoast Water proposes to better manage water supply and quality by: (a) implementing strategies for improvements in use efficieney; and (b) developing a borefield as an alternative souree in wallum on a series of Pleistocene barriers at Nabiac (Watkins et al. 2006).

The Nabiac barriers (32° 09'S 152° 26'E, Figure 1) have a surface area of approximately 45 km^2 and eontain two aquifers – a shallow unconfined aquifer about 2–3 m deep above an indurated sand layer (aquitard) 3–5 m thick, and a semi-confined aquifer 15–20 m deep below the indurate and above basement clay sediments and bedrock (Acacia Environmental Planning 2004). The shallow aquifer is primarily recharged by direct rainwater infiltration, the deep aquifer is in turn recharged by leakage through the indurate from the shallow aquifer, and groundwater eventually discharges into Wallis Lake via MeClymonts Creek and the Wallamba and Coolongolook Rivers. The aquifers and indurated layer have a combined storage capacity of approximately 195 000 ML, and preliminary tritium analysis suggests an age of 5–10 years for water in the deeper aquifer (Aeacia Environmental Planning 2004). The Nabiac barriers are a key geomorphic unit of the Wallis Lake catchment, and this region is significant for nature conservation, tourism, recreational and commercial fishing, and oyster farming (Great Lakes Council 2003).

Despite an expected increase in demand for groundwater from sand mass aquifers, research into the potential impacts of extraction upon groundwater-dependent ecosystems is generally lacking and therefore a high priority (ARMCANZ/

ANZECC 1996, NSW Government 2002). An investigation of the mechanisms of groundwater utilisation by wallum at Nabiac is proposed as an integral part of monitoring for potential impacts of borefield operation. It is envisaged that this research will have broader application to the wallum ecosystem throughout eastern Australia. On this basis the degree to which the Nabiac study area is representative of wallum in general has been assessed, and the findings of a comparative assessment of floristic composition and spatial patterns are presented herein. Although wallum on the Nabiac barriers is the primary focus of this paper, the vegetation on adjacent bedrock, estuarine and alluvial landforms is also described to improve the context of discussion about floristic patterns and conservation significance.

Climate

The climate of coastal northern NSW is subtropical with summer-dominant rainfall, although with increasing latitude there is a gradual shift towards temperate conditions and relatively uniform rainfall throughout the year (Colls & Whitaker 1990).

The Bureau of Meteorology provides climatic data for Taree (rainfall 100+ years; temperature 80+ years), which is similar in altitude (5 m a.s.l.) to the Nabiac barriers although 25 km further north. Here the average rainfall during the three wettest months (January to March) accounts for 35% of the mean annual total (1179 mm), whereas 17% falls during the three driest months (July to September). Monthly means are positively skewed relative to median values, and therefore rainfall tends to be more often drier than average in any month rather than wetter than average. Despite the average trends, the variability index [VI = (9th decile – 1st decile)/5th decile] for monthly rainfall ranges from 1.9–4.5. Relative to other parts of Australia these VI values are considered to be very high (1.5–2.0) or extreme (>2.0), and episodes of drought and flood are therefore likely.

Taree has a mean annual maximum temperature of 24.2°C and a mean annual minimum of 12.0°C. Mean monthly maxima are highest from December to February (28.3–28.9°C), lowest from June to August (18.4–19.9°C), and mean monthly diurnal variation is 10.9–13.9°C. The highest recorded temperatures are around 43°C in late spring and summer, and the lowest are –2 to –5°C during late autumn and winter.

Mean monthly 9 am relative humidity for Taree varies from 67–80%, and for 3 pm the range is 51–63%. Lower values predominantly occur from mid-winter to late spring, which is also the period of generally lower mean monthly rainfall. At this time of year, during the so-called late winter – spring 'drought' of Coaldrake (1961), conditions of water deficit may arise when evaporation is high relative to rainfall.

Landforms, geology and soils

The study area is part of the Tuncurry bedrock embayment, which has formed over the last three interglacial cycles (Roy et al. 1997). The embayment comprises several barrier systems of marine-aeolian sand with associated estuarine and alluvial deposits (Melville 1984, Roy et al. 1997). The Pleistocene Nabiac barriers, west of the Wallamba River, range in age from around 80 to 260 ka. These are distinguished from the Holocene Tuncurry barrier (8–1 ka), east of the Wallamba River, which forms the present embayment shoreline (Figure 1). The Coolongolook – Wallingat River system has intersected the Nabiac barriers in the south, forming Wallis Island, and the Wallamba River intersects the barriers in the north (Roy et al. 1997).

Three beach ridge barriers with associated interbarrier and backbarrier flats (plains) dominate the study area, although localised dunefields occur at the northern and southern extremities (Melville 1984). These Pleistocene beach ridges and dunes are now degraded, probably due at least in part to the erosive force of raindrop splash (Thompson 1983); and the poorly defined, widely spaced ridges and swales (2–7 m a.s.l.) contrast with the well-defined relief of the approximately 60 shore-parallel beach ridges comprising the Holocene Tuncurry barrier (Melville 1984, Roberts et al. 1991, Roy et al. 1997).

Bedrock rises and low hills formed from the Bundook beds (Late Devonian), Booti Booti Sandstone and the Wallanbah Formation (both Early Carboniferous) adjoin the Nabiac barriers to the west and south-west, and dominant lithologies of these stratigraphic units include greywacke, lithic sandstone, mudstone and siltstone (Roberts et al. 1991). Alluvial and estuarine landforms derived from Pleistocene or Holocene deposits occur closer to Wallis Lake and its tributaries (Murphy 2005).

Soils derived from the quartzose sand of the Nabiac barriers form a catenary sequence from Podzols on well-drained sites to Humus Podzols where drainage is imperfect to poor; and Acid Peats replace podzols lower in the landscape where waterlogging is severe (Murphy 2005). Podzols dominate on the Tuncurry barrier, although Siliceous Sands and Acid Peats occur over limited areas. Siliceous Sands, Acid Peats, Humic Gleys and Solonchaks are found on estuarine landforms, whereas the soils associated with alluvial landforms include Brown Podzolic Soils, Yellow Earths and Humic Gleys. Nearby bedrock soils form toposequences, and these vary from Lithosols and Red Podzolic Soils on crests and steeper slopes, to Red, Brown and Yellow Podzolic Soils on gentler slopes, and Soloths on lower slopes and along drainage lines.

Landuse and fire history

The Worimi and Biripai Aboriginal tribes inhabited distinct, adjoining territories in the Nabiac-Tuncurry region at the time of European settlement. However, white settlers along the Manning River soon dispersed the Biripai southwards, disrupting tribal boundaries and forcing them to intermingle with the Worimi. Physical evidence of a rich Aboriginal culture includes middens, open campsites and stone artefact scatters, ceremonial grounds, and carved or otherwise scarred trees, generally in close proximity to estuaries and swamps (Collins 2004, Gilbert 1954a,b).

The Nabiac district was part of the original Australian Agricultural Company grant of the 1820s, although this and other coastal areas were soon relinquished to the Crown in exchange for lands further inland that were deemed more suitable for agricultural pursuits such as sheep grazing. Timber cutters were operating in the district by the early 1830s, initially with permits to harvest Red Cedar (*Toona ciliata*). Henry Carmichael purchased the first land grant (46.6 ha) along the Wallamba River in 1855, and by 1866 the Wallis Lake area, known at the time as Cape Hawke Settlement, was a small agricultural and timber-cutting community (Gilbert 1954a). Sections of the Nabiac barriers are revegetating following mineral sand mining, initially by Mineral Deposits Ltd during the mid 1970s to early 1980s and then by R.Z. Mines Pty Ltd during the 1990s (Acacia Environmental Planning 2004, Resource Planning 1990). Forster Local Aboriginal Land Council holds freehold title over much of the Nabiac wallum.

The Wallis Lake flora soon attracted the attention of colonial botanists, and in 1864 local Aboriginals assisted Robert Fitzgerald with the collection of a Rock Lily (*Dendrobium* sp.) on Wallis Island (Gilbert 1954a). Other noteworthy collections include the type specimens of *Allocasuarina defungens* and *A. simulans* (Casuarinaceae), obtained from the Nabiac barriers by R. G. Coveny and colleagues (Johnson 1989). Armidale historian L.A. Gilbert also collected numerous plants at Nabiac during the 1940s and 1950s, and specimens are housed in the N.C.W. Beadle Herbarium (NE) at the University of New England.

Deliberate burning of the Nabiac wallum has apparently occurred on a regular basis in the recent past to promote flowering in Christmas Bells, *Blandfordia grandiflora* for the cut-flower trade (Acacia Environmental Planning 2004). It is also likely that fire was used to promote green pick in the understorey of forests and woodlands for livestock grazing. The impact of fire frequency upon native vegetation in NSW is understood in broad terms, and current management prescriptions to maintain biodiversity in coastal vegetation such as the Nabiac wallum advocate a domain of acceptable fire intervals between approximately 7 and 30(–35) years (Bradstock et al. 2003). The impacts of fire intensity and season of burn are less well known, although a general guiding principle is to vary both as much as possible at any given locality (Bradstock et al. 2003). The same generalisation applies for fire frequency within the recommended intervals (e.g. Morrison *et al.* 1995).

Methods

Data collection

The vegetation of the Nabiac barriers and adjoining bedrock, estuarine and alluvial landforms was mapped from 1:25 000 aerial photography using conventional air photo interpretation (API), in a manner consistent with earlier mapping of coastal vegetation throughout much of north-eastern NSW (e.g. Griffith et al. 2000). API groups (map units) were primarily distinguished by growth form (after Walker & Hopkins 1984) and species dominance in the dominant (generally tallest) stratum. When circumscribed in this manner, API groups are generally analogous to plant associations sensu Beadle (1981): 'a community in which the dominant stratum exhibits uniform floristic composition, the community usually exhibiting uniform structure (also)'. The vegetation mapping formed the basis of sample stratification in the wallum, and the following data were collected in randomly placed quadrats at 27 remotely chosen sites (NAB001.1–027.1).

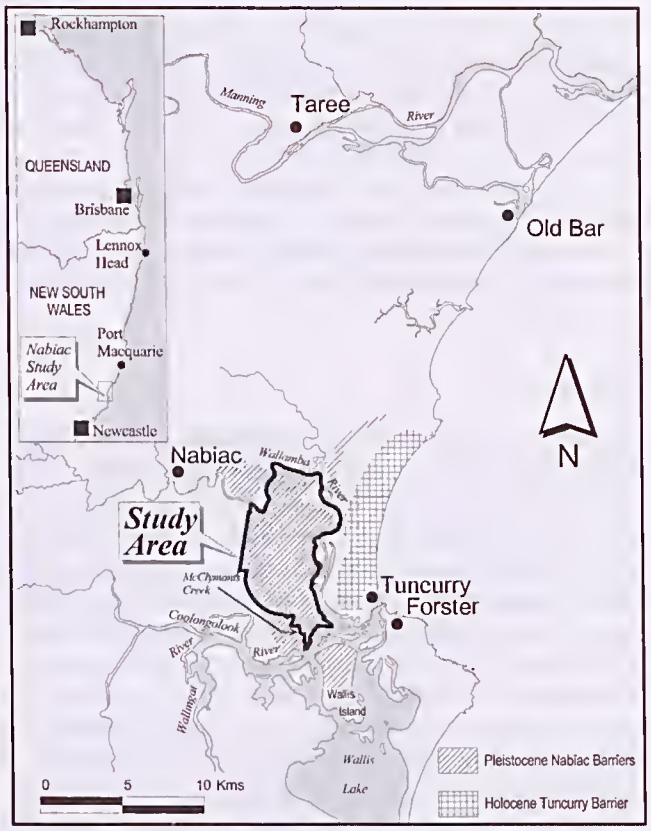


Fig. 1. Locality map of the Nabiac study area.

(a) Foliage cover (sensu Walker & Hopkins 1984) score for each vascular species in 25 m^2 (sedgeland), 100 m^2 (heathland, shrubland, mallee woodland) or 400 m^2 (forest, woodland) quadrats: 1 (<1%); 2 (1–5%); 3 (6–25%); 4 (26–50%); 5 (51–75%); and 6 (76–100%).

(b) Geology from available mapping, in this case only QSA (Quaternary sand or alluvium).

(c) Aspect (°).

(d) Slope (°).

(e) Altitude above sea level (m).

(f) Topographic position (after Speight 1984) using categories for landform morphological type (D = closed depression, F = flat, R = ridge, V = open depression) and landform element (BRI = beach ridge, DDE = drainage depression, DUN = dune, PLA = plain, SWL = swale, SWP = swamp).

(g) Geographic location (easting and northing).

(h) Degree of exposure, determined as the azimuth (°) for each of the eight principal compass bearings (N, NE, etc.).

(i) Time elapsed since last burnt (0–5 years, 5–10 years, or >10 years), estimated from counts of incremental post-fire branching in calibrated species (*Banksia ericifolia* subsp. *macrantha* and *B. oblongifolia*).

The Nabiac data are compatible with another dataset of approximately 500 quadrats for wallum and allied vegetation (other than forest and woodland) along 400 km of coastline in NSW from the Manning River north to the Lennox Head district (Griffith 2002, Griffith et al. 2003). The data from elsewhere were used for a comparative study of the Nabiac wallum. The nomenclature is generally consistent with current usage at the Royal Botanic Gardens (Sydney), and authorities are provided in Harden (1990–3, 2002) or Harden and Murray (2000).

Data analysis

Numerical analysis of foliage cover scores (1 to 6) without further transformation was performed using PATN (Belbin 1993). The Bray-Curtis association coefficient was employed in combination with the flexible UPGMA (unweighted pair group arithmetic averaging) clustering algorithm and a slightly negative (-0.1) beta value. Kent and Coker (1992) suggest that an appropriate numerical method, and hence classification, is one 'which enables a clear ecological interpretation to be made'. The Bray-Curtis coefficient was found to satisfy this requirement, and such an outcome is consistent with a view that it provides a good estimate of ecological distance, primarily because greater emphasis is placed upon similarity between common and abundant species, than upon similarity between rare species and those with low cover-abundance (Belbin 1992, 1993, Faith et al. 1987).

The data were further examined for spatial relationships between plant species and environmental variables using Canonical Correspondence Analysis (CCA). This is a multivariate method of direct ordination in which correlation and regression procedures are integrated. It depicts both patterns in floristic composition and the principal relationships with environmental variables. Biplots present the ordination output, and these display quadrats as points, numerical environmental variables as vectors, and categorical environmental variables as centroids. The ordinations were performed in an unconstrained manner (i.e. without *a priori* intuitive weighting of variables) using CANOCO (ter Braak 1988). Monte Carlo permutations (n = 999), using the eigenvalue for the first ordination axis as the test statistic, allowed examination of the null hypothesis that floristic composition is independent of the environmental variables; where P = (no. of permutations with test statistic equal to or higher than original data + 1)/(no. of permutations + 1).

Analyses were performed on the Nabiac dataset in isolation, and also on combinations of the Nabiac data for mallee, shrubland, heathland and sedgeland with data for these structural formations elsewhere in north-eastern NSW.

Results and Discussion

Wallum on the Nabiac barriers and associated flats

Dry sclerophyll forest and woodland (DSF/W)

Structure: mid-high to very tall, open woodland to closed forest.

Floristic composition: *Eucalyptus racemosa* subsp. *racemosa* is a widespread forest and woodland dominant on the Nabiac barriers (DSW in Figures 2, 3). Other large stands are dominated by *Eucalyptus pilularis* with associated *Angophora costata* (DSF–1), whereas *Eucalyptus globoidea* (DSF–2) dominates localised stands. *Corymbia gummifera*, *Eucalyptus piperita* or *E. resinifera* may be present as minor species in the tallest stratum of these forests and woodlands. Understorey species include *Banksia aemula*, *B. serrata* (+/- continuous with the tallest stratum), *Coleocarya gracilis*, *Dillwynia retorta*, *Eriostemon australasius*, *Leptospermum polygalifolium* subsp. *cismontanum*, *L. trinervium*, *Leucopogon ericoides*, *Leucopogon leptospermoides*, *Monotoca elliptica*, *M. scoparia*, *Petrophile pulchella* and *Pteridium esculentum*.

Habitat and community relations: Found on ridges (dunes, beach ridges) where the watertable is likely to be deeper than in soils supporting dry sclerophyll mallee woodland or dry sclerophyll shrubland.

Distribution and equivalent vegetation types: *Eucalypts racemosa* subsp. *racemosa* (previously *E. signata*) has a widespread distribution along the coast of NSW and southern Queensland (Pfeil & Henwood 2004) where it occurs on both sand masses and bedrock soils. Wallum occurrences of *E. racemosa* subsp. *racemosa* forest and woodland are reported for other localities in north-eastern NSW and south-eastern Queensland (e.g. Clifford & Specht 1979, Durrington 1977, Osborn & Robertson 1939, Pressey & Griffith 1992). *Eucalyptus pilularis* – *A. costata* dry sclerophyll forest occurs elsewhere in wallum on the lower North Coast in Booti Booti NP (Griffith et al. 2000) and Myall Lakes NP (Myerscough & Carolin 1986). *Eucalyptus pilularis* forests on sand in which other species associate (e.g. *Corymbia gummifera*, *C. intermedia*, *E. planchoniana*) extend to the upper North Coast (e.g. Forestry Commission of NSW (1989) as forest type No.

41 'Sandhill Blackbutt', Pressey & Griffith 1992) and continue into southern Queensland (Clifford & Specht 1979, Durrington 1977). *Eucalyptus globoidea* appears to be absent as a forest dominant in wallum to the north of Nabiac.

Swamp sclerophyll forest and woodland (SSF/W)

Structure: mid-high to very tall, open woodland to closed forest.

Floristic composition: The tallest stratum is dominated by *Eucalyptus robusta* (SSF–1 in Figures 2, 3) or *Melaleuca quinquenervia* (SSF–2), although some stands of *E. robusta* support a distinct second tree stratum of *Melaleuca sieberi* (SSW). Understorey composition varies, although common species include *Baloskion tetraphyllum* subsp. *meiostachyum*, *Banksia oblongifolia*, *B. robur*, *Baumea articulata*, *Empodisma minus*, *Gahnia clarkei*, *G. sieberiana*, *Gleichenia microphylla*, *Leptocarpus tenax*, *Leptospermum liversidgei*, *Livistona australis* (+/- continuous with the tallest stratum), *Melaleuca sieberi*, *Pultenaea villosa*, *Schoenus brevifolius*, *Sporadanthus interruptus* and *Xanthorrhoea fulva*.

Habitat and community relations: Occupies open depressions (e.g. swales, drainage depressions) and poorly-drained flats. Also borders closed depressions (swamps).

Distribution and equivalent vegetation types: Swamp sclerophyll forest and woodland dominated by *Melaleuca quinquenervia* or *Eucalyptus robusta* extends along the NSW North Coast (Forestry Commission of NSW 1989, Griffith et al. 2000, Myerscough & Carolin 1986, Pressey & Griffith 1992), and similar vegetation occurs in south-eastern Queensland (Batianoff & Elsol 1989; Dowling & McDonald 1976; Durrington 1977; Elsol & Dowling 1978).

Dry sclerophyll mallee woodland (DSMW)

Structure: very tall open mallee woodland and mallee woodland.

Floristic composition: *Eucalyptus racemosa* subsp. *racemosa* is a widespread mallee on the Nabiac barriers. Common understorey species include *Acacia quadrilateralis*, *Banksia aemula*, *Eriostemon australasius*, *Hypolaena fastigiata*, *Leptospermum polygalifolium*

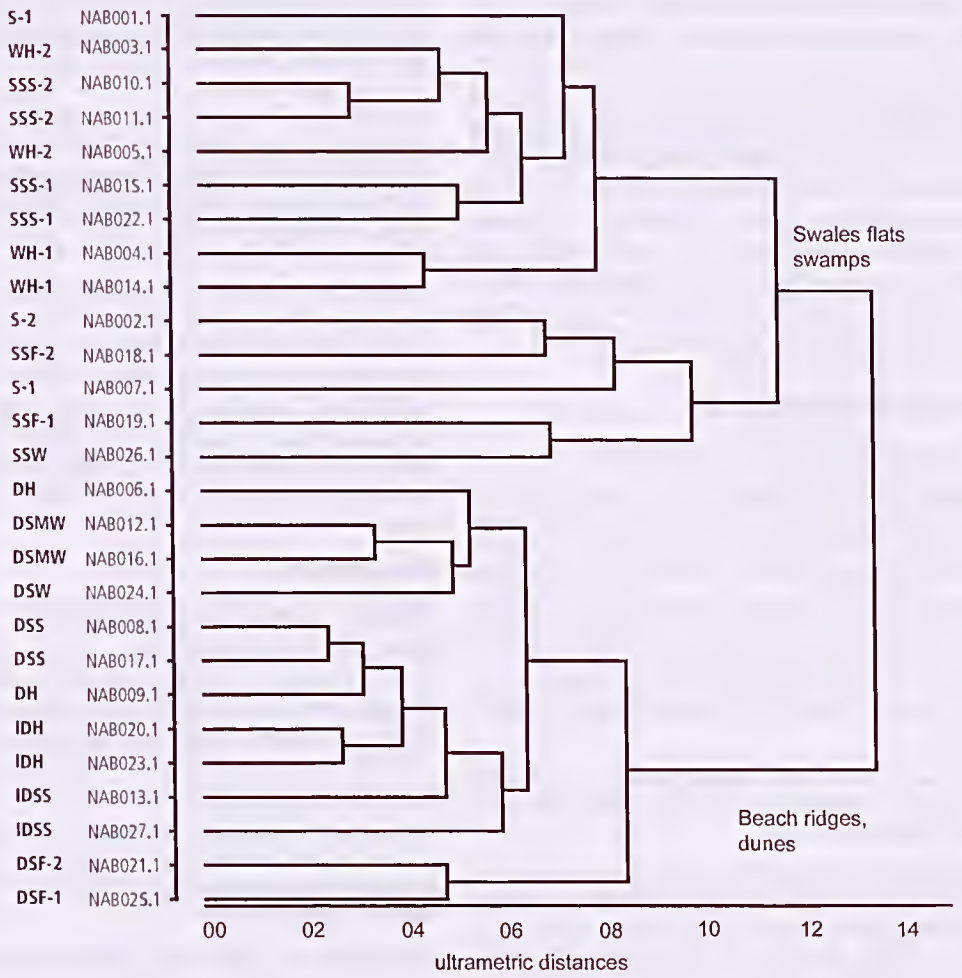


Fig. 2. Numerical classification of floristic data for wallum at Nabiae.

DH: *Banksia aemula* dry heathland; DSF-1: *Eucalyptus pilularis – Angophora costata* dry sel. forest; DSF-2: *Eucalyptus globoidea* dry sel. forest; DSMW: *Eucalyptus racemosa* dry sel. mallee woodland; DSS: *B. aemula* dry sel. shrubland; DSW: *E. racemosa* dry sel. woodland; IDH: intermediate dry heathland; IDSS: intermediate dry sel. shrubland; S-1: *Leptocarpus tenax – Baloskion pallens* etc. sedgeland; S-2: *Baumea articulata* sedgeland; SSF-1: *Eucalyptus robusta* swamp sel. forest; SSF-2: *Melaleuca quinquenervia* swamp sel. forest; SSS-1: *Banksia ericifolia* swamp sel. shrubland; SSS-2: *Melaleuca sieberi* swamp sel. shrubland; SSW: *E. robusta – M. sieberi* swamp sel. woodland; WH-1: *Banksia oblongifolia – Leptospermum liversidgei* etc. wet heathland; WH-2: *B. oblongifolia – Hakea teretifolia* etc. wet heathland. The foliage cover data are provided as Appendix 1.

subsp. *cismontanum*, *L. semibaccatum*, *L. trinervium*, *Leucopogon ericoides*, *Melaleuca nodosa*, *Monotoca scoparia*, *Ochrosperma lineare* and *Philotheca salsolifolia* subsp. *salsolifolia*; and some of these may be more or less continuous with the tallest stratum (e.g. *B. aemula*).

Habitat and community relations: Found on beach ridges. This formation is floristically similar to *E. racemosa* subsp. *racemosa* forest and woodland (Figures 2, 3).

Distribution and equivalent vegetation types: *Eucalyptus racemosa* subsp. *racemosa* mallee has a sporadic distribution on the NSW North Coast (Griffith et al. 2003), and is reported for south-eastern Queensland (Durrington 1977).

Dry sclerophyll shrubland (DSS)

Structure: tall to very tall, open to sparse shrubland.

Floristic composition: *Banksia aemula* is the characteristic dominant. *Caustis recurvata* var. *recurvata*, *Hypolaena fastigiata*, *Leptospermum polygalifolium* subsp. *cismontanum*, *L. semibaccatum*, *Leucopogon ericoides*, *Melaleuca nodosa*, *Ochrosperma lineare* and other species form a somewhat continuous understorey, certain of which (e.g. *M. nodosa*) may merge and associate with *B. aemula* in the absence of fire for long periods.

Habitat and community relations: Found on ridges (e.g. beach ridges). This subformation is floristically similar to dry heathland, and affinities are also apparent with *Eucalyptus racemosa* subsp. *racemosa* dry sclerophyll woodland and mallee (Figures 2, 3).

Distribution and equivalent vegetation types: *Banksia aemula* dry sclerophyll shrubland is widespread on the NSW North Coast (Griffith et al. 2000, Griffith et al. 2003). Similar vegetation is reported for the NSW Central Coast (Benson & Howell 1990) and south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977, Sattler & Williams 1999).

Swamp sclerophyll shrubland (SSS)

Structure: tall to very tall shrubland and closed shrubland.

Floristic composition: *Banksia ericifolia* subsp. *macrantha* dominates swamp sclerophyll shrubland in swales (SSS–1 in Figures 2, 3), where understorey species include *Banksia oblongifolia*, *Boronia falcifolia*, *Eurychorda complanata*, *Lepidosperma filiforme*, *Leptospermum liversidgei*, *Sporadanthus interruptus*, *Xanthorrhoea fulva* and *Xyris operculata*. *Melaleuca sieberi* also forms a shrubland on flats (SSS–2), where understorey species include *Baloskion pallens*, *Banksia oblongifolia*, *Lepidosperma limicola*, *Leptocarpus tenax*, *Leptospermum arachnoides*, *Melaleuca thymifolia*, *Ptilothrix deusta* and *Xyris operculata*.

Habitat and community relations: Occupies poorly drained open depressions (swales) and interbarrier flats, where a shallow watertable periodically rises to the ground surface.

Distribution and equivalent vegetation types: *Banksia ericifolia* subsp. *macrantha* is restricted to the North Coast in NSW (Harden 2002), and shrublands dominated by this species extend north from the Forster district (Griffith et al. 2003). *Melaleuca sieberi* is more widespread, dominating swamp sclerophyll shrubland on the NSW Central Coast (Benson 1986) and North Coast (Griffith et al. 2003), and forming equivalent or similar shrublands in south-eastern Queensland (Dowling & McDonald 1976).

Dry heathland (DH)

Structure: mid-high to tall closed heathland.

Floristic composition: *Banksia aemula* is the characteristic dominant, although other subsidiary or co-dominant heath shrubs include *Leptospermum semibaccatum*, *Melaleuca nodosa*, *Monotoca scoparia* and *Ochrosperma lineare*. The sedges *Caustis recurvata* var. *recurvata* and *Hypolaena fastigiata* are generally conspicuous.

Habitat and community relations: Found on beach ridges. Dry heathland has floristic affinities with *Banksia aemula* dry sclerophyll shrubland, and *Eucalyptus racemosa* subsp. *racemosa* dry sclerophyll woodland and mallee woodland (Figures 2, 3).

Distribution and equivalent vegetation types: *Banksia aemula* dry heathland extends north from the NSW Central Coast into south-eastern Queensland (Adam et al. 1989, Batianoff & Elsol 1989, Durrington 1977, Griffith et al. 2000, Griffith et al. 2003, McRae 1990, Myerscough & Carolin 1986), although subsidiary or co-dominant species vary with latitude.

Wet heathland (WH)

Structure: mid-high to tall closed heathland.

Floristic composition: This subformation is floristically variable. Co-dominant or subsidiary heath shrubs in swales (WH-1 in Figures 2, 3) include *Banksia ericifolia* subsp. *macrantha*, *B. oblongifolia*, *Boronia falcifolia*, *Epacris microphylla* var. *microphylla*, *Leptospermum liversidgei*, *Sprengelia incarnata* and *Xanthorrhoea fulva*, whereas *Empodisma minus*, *Gahnia sieberiana*, *Schoenus scabripes* and *Sporadanthus interruptus* are conspicuous sedges. Frequent species on flats (WH-2) include the heath shrubs *Banksia oblongifolia*, *Hakea teretifolia* subsp. *teretifolia*, *Leptospermum arachnoides* and *Xanthorrhoea fulva*, along with the sedges *Lepidosperma neesii*, *Leptocarpus tenax* and *Ptilothrix deusta*. Some of the heterogeneity in floristic composition may be attributed to fire, where frequent burning limits recruitment of seeders (e.g. *B. ericifolia* subsp. *macrantha*, *H. teretifolia* subsp. *teretifolia*, *L. arachnoides*).

Habitat and community relations: Characteristic of poorly drained open depressions (swales) and flats with a shallow watertable. In the absence of fire for extended periods, *B. ericifolia* subsp. *macrantha* may overtop shorter species to dominate as a swamp sclerophyll shrubland.

Distribution and equivalent vegetation types: Wallum wet heathland of similar floristic composition is widespread in north-eastern NSW (Griffith et al. 2000, Griffith et al. 2003) and south-eastern Queensland (Batianoff & Elsol 1989, Clifford & Specht 1979, Durrington 1977, Elsol & Dowling 1978).

Sedgeland (S)

Structure: tall to very tall closed sedgeland.

Floristic composition: *Baumea articulata* dominates in deep swamps (S–2 in Figures 2, 3), whereas *Baloskion pallens*, *Baumea teretifolia*, *Chorizandra sphaerocephala*, *Lepidosperma limicola*, *Leptocarpus tenax* and *Schoenus brevifolius* are some of the co-dominant or subsidiary species in floristically variable shallow swamps (S–1) along with certain heath shrubs (e.g. *Callistemon pachyphyllus*).

Habitat and community relations: Occupies closed depressions (swamps) where standing water accumulates, and often replaced by wet heathland, swamp sclerophyll shrubland or swamp sclerophyll forest as surface drainage improves.

Distribution and equivalent vegetation types: *Baumea articulata* sedgeland is known for other locations on the NSW North Coast (Bell 1997, Griffith et al. 2003, Pressey & Griffith 1987), and it is likely to form part of a *B. articulata* – *Cladium procerum* – *Lepironia articulata* vegetation unit reported for south-eastern Queensland (McDonald & Elsol 1984). Comparatively shallow sedgelands of *Baloskion pallens*, *Baumea teretifolia* and associated species are widespread in the wallum of north-eastern NSW (Bell 1997, Griffith et al. 2000, Griffith et al. 2003), and similar or related sedgelands occur in south-eastern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Elsol & Dowling 1978).

Vegetation associated with bedrock, estuarine and alluvial landforms

Mangrove forest and woodland

Structure: low to mid-high, open woodland to open forest (grading into tall to very tall, sparse to closed shrubland).

Floristic composition: *Avicennia marina* subsp. *australasica* dominates, and *Aegiceras corniculatum* may be present as an understorey, particularly where the tallest stratum is diffuse. The immediate ground surface is generally unvegetated except for pneumatophores, although saltmarsh species such as *Juncus kraussii* subsp. *australiensis* can occupy gaps in the tallest stratum.

Habitat and community relations: Found on intertidal flats of the Wallis Lake estuary. *Juncus kraussii* subsp. *australiensis* rushland or *Baumea juncea* sedgeland replaces the mangroves at slightly higher elevations.

Distribution and equivalent vegetation types: *Avicennia marina* subsp. *australasica* mangrove forest and woodland is widespread along the NSW coast (Beadle 1981, Adam et al. 1988, West et al. 1984), and extends into Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1982, Durrington 1977).

Wet sclerophyll forest

Structure: tall to very tall, open to closed forest.

Floristic composition: *Eucalyptus grandis* dominates, with *Casuarina glauca* and *Melaleuca quinquenervia* present as associates. Understorey species include *Gahnia clarkei*, *Livistona australis*, *Melaleuca linariifolia*, *M. styphelioides*, *Oplismenus* spp. and *Viola banksii*. The understorey is generally less mesic than expected, possibly due to frequent ground fires and livestock grazing.

Habitat and community relations: Found on flats associated with alluvial backswamps, often where barrier sands interface, and grades into swamp sclerophyll forest as soil drainage deteriorates.

Distribution and equivalent vegetation types: *Eucalyptus grandis* reaches its southern distribution limit in the vicinity of Newcastle on the lower North Coast (Chippendale 1988, Harden 2002), and forests dominated by this species are described by others for north-eastern NSW and south-eastern Queensland (Beadle 1981, Elsol & Dowling 1978, Forestry Commission of NSW (1989) as forest type No. 48 'Flooded Gum', Griffith et al. 2000, McDonald & Whiteman 1979).

Dry sclerophyll forest and woodland

Structure: tall to very tall, woodland to closed forest.

Floristic composition: *Eucalyptus pilularis* is a common dominant or co-dominant of dry sclerophyll forest on bedrock rises and low hills, although other stands are characterised by *Eucalyptus eugenioides*, *E. siderophloia* and *Corymbia intermedia*. *Corymbia maculata* is also locally dominant in forest and woodland. Associates in these bedrock forests include *Eucalyptus acmenoides*, *E. microcorys*, *E. propinqua*, *E. resinifera* and *E. tereticornis*. Smaller areas of dry sclerophyll forest and woodland occupy flats nearer the Wallamba River, where barrier and alluvial sediments are likely to intergrade. *Eucalyptus tereticornis* and *C. intermedia* primarily co-dominate on these flats, whereas *Angophora costata* is a less common dominant. Understorey composition varies, although likely species include

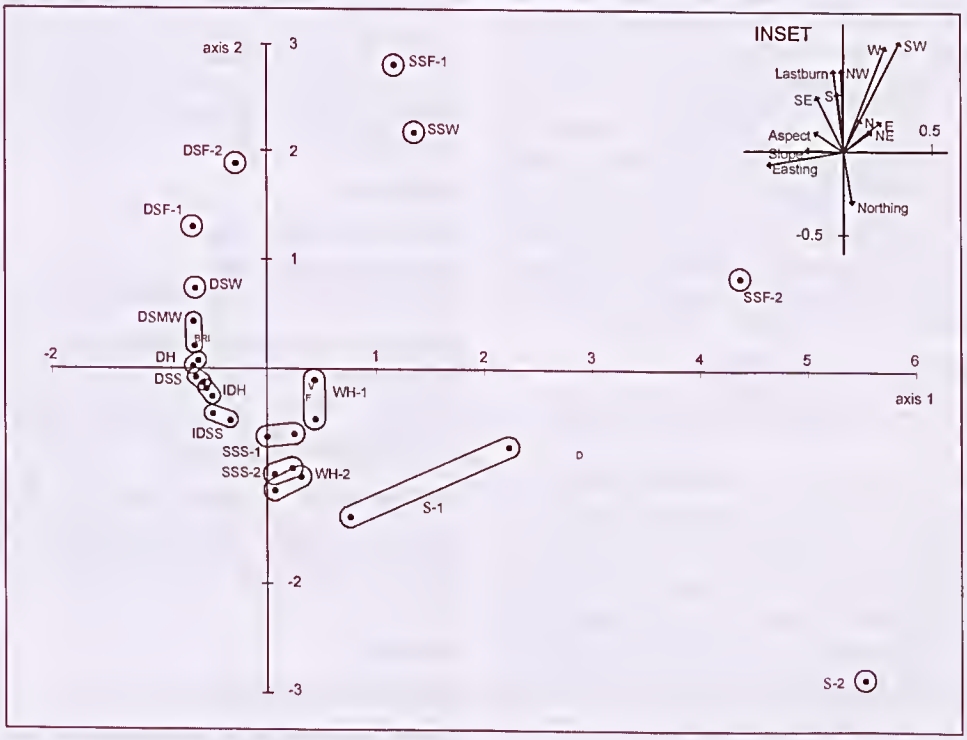


Fig. 3. Ordination of floristic and environmental data for wallum at Nabiac.

Eigenvalues: axis 1 = 0.8217; axis 2 = 0.5496. Axis 1 is significant (P = 0.03). CANOCO excluded invariate (e.g. altitude, as all sites <10 m) and collinear (e.g. SWP (swamp) with D) variables. BRI = beach ridge; D = closed depression; F = flat; V = open depression. For an explanation of formation and subformation abbreviations, see Figure 2.

Allocasuarina littoralis, *A. torulosa*, *Imperata cylindrica* var. *major*, *Jacksonia scoparia*, *Lepidosperma laterale*, *Leucopogon juniperinus*, *L. lanceolatus* var. *gracilis*, *Melaleuca nodosa*, *M. styphelioides*, *Persoonia linearis*, *Pteridium esculentum* and *Themeda australis*.

Habitat and community relations: Typical of hillcrests and hillslopes on bedrock rises and low hills, although also scattered on flats. Dry sclerophyll forest and woodland is replaced by the swamp equivalents as soil drainage deteriorates, and boundaries between these subformations may be gradational in areas of minimal relief.

Distribution and equivalent vegetation types: *Eucalyptus pilularis* is a widespread dominant of dry sclerophyll forest in coastal districts of NSW (Forestry Commission of NSW (1989) as forest type No. 37 'Dry Blackbutt', Griffith et al. 2000), and similar forests occur in south eastern Queensland (Elsol 1991, McDonald & Whiteman 1979). *Eucalyptus eugenioides*, *E. siderophloia* and *Corymbia intermedia* are characteristic dominants of coastal forests elsewhere in north-eastern NSW (e.g. Bundjalung and Yuraygir National Parks – S.J.G. and R.W. unpublished), and these would fall within the broader forest type 126 'Stringybark – Bloodwood' (Forestry Commission of NSW 1989). Related forests in which *E. eugenioides* associates with various species (including *C. intermedia*, *E. crebra*, *E. microcorys* and *E. tereticornis*) occur in south-eastern Queensland (McDonald & Whiteman 1979). *Corymbia maculata* has a predominantly coastal distribution south from the Manning River district (Hill & Johnson 1995), and forest dominated by this species falls within the *Corymbia maculata* s. lat. alliance of Beadle (1981) and the 'Spotted Gum' (*C. variegata*/*C. maculata*/*C. henryi*) forest type No. 70 of the Forestry Commission of NSW (1989), both of which are widespread in coastal NSW. Elsewhere in the Wallis Lake area, *C. maculata* dry sclerophyll forest occurs in Booti Booti National Park (Griffith et al. 2000). *Eucalyptus tereticornis* and *Corymbia intermedia* co-dominate dry sclerophyll forest or woodland elsewhere on the lower North Coast of NSW, for example in Hat Head NP, Limeburners Creek Nature Reserve and Lake Innes NR (S.J.G. and R.W. unpublished). *Eucalyptus tereticornis* and *C. intermedia* commonly associate with *Lophostemon suaveolens* on the upper North Coast (e.g. Pressey & Griffith 1992), although the latter species reaches its southern limit of distribution in the vicinity of Kempsey (Harden 2002). Equivalent forests and woodlands of *E. tereticornis* and *C. intermedia* (+/- *L. suaveolens*) occur in south-eastern Queensland (Durrington 1977, Elsol 1991). *Angophora costata* is endemic to NSW where it has a predominantly coastal distribution south from the Evans River on the far North Coast (Bale 1992, Harden 2002). Dry sclerophyll forest or woodland dominated by *A. costata* is reported for other localities (Benson 1986, Forestry Commission of NSW 1989, Griffith et al. 2000, Myerscough & Carolin 1986).

Swamp sclerophyll forest and woodland

Structure: (occasionally low to) mid-high to very tall, open woodland to closed forest.

Floristic composition: *Casuarina glauca*, *Eucalyptus robusta* and *Melaleuca quinquenervia* form more-or-less mono-dominant stands, although it is not uncommon for *M. quinquenervia* and *C. glauca* to co-occur, or alternatively *M. quinquenervia* and *E. robusta*. Minor associates in the tallest stratum include *Corymbia intermedia* and *Eucalyptus tereticornis*. *Livistona australis* and *M. quinquenervia* also co-dominate some stands, and *M. nodosa* dominates localised areas of low to mid-high swamp sclerophyll forest. The understorey is variable, probably reflecting not only site differences (e.g. extent of waterlogging and salinity) but also management (e.g. fire and livestock grazing), although likely species include *Baumea juncea*, *Entolasia stricta*, *Gahnia clarkei*, *Goodenia ovata*, *Imperata cylindrica* var. *major*, *Ischaemum australe*, *Lepidosperma quadrangulatum*, *Leptinella longipes*, *Livistona australis* (sometimes +/- continuous with the tallest stratum), *Melaleuca ericifolia*, *M. linariifolia*, *M. styphelioides* and *Phragmites australis*.

Habitat and community relations: Primarily associated with poorly drained alluvial backswamps and estuarine plains, although minor stands of *Melaleuca nodosa* occur on transferral drainage plains below bedrock rises. Dry sclerophyll forest and woodland often replaces the swamp equivalents as soil drainage improves.

Distribution and equivalent vegetation types: Swamp sclerophyll forest or woodland dominated by *Casuarina glauca*, *Melaleuca quinquenervia* or *Eucalyptus robusta* is reported by others for coastal districts of NSW (Forestry Commission of NSW 1989, Goodrick 1970, Griffith et al. 2000, Myerscough & Carolin 1986, Pressey & Griffith 1992) and southern Queensland (Batianoff & Elsol 1989, Dowling & McDonald 1976, Durrington 1977, Elsol & Dowling 1978, McDonald & Whiteman 1979). Similar or related swamp sclerophyll forests of *Livistona australis* and *M. quinquenervia* are also known for other parts of north-eastern NSW (Myerscough & Carolin 1986, Osborn & Robertson 1939) and south-eastern Queensland (Elsol & Dowling 1978, McDonald & Elsol 1984), and these have affinities with *L. australis* subtropical ('palm', 'swamp') rainforest (Floyd 1990, Forestry Commission of NSW 1989, Griffith et al. 2000, Harden et al. 2006). *Melaleuca nodosa* appears to have a scattered distribution as a forest (or shrubland) dominant in coastal NSW and southern Queensland (e.g. Benson 1986, Coaldrake 1961, Elsol & Dowling 1978).

Swamp sclerophyll shrubland

Structure: tall to very tall closed shrubland.

Floristic composition: *Melaleuca ericifolia* dominates. Understorey species include *Baumea juncea*, *Ischaemum australe* and *Leptocarpus tenax*.

Habitat and community relations: Found on flats near the Wallis Lake estuary, at slightly higher elevations than saltmarsh vegetation such as *Juncus kraussii* subsp. *australiensis* rushland.

Distribution and equivalent vegetation types: The distribution of *Melaleuca ericifolia* extends south along the NSW coast from the Hastings River district (lower North Coast), and continues into Victoria and Tasmania (Harden 2002). The species is known to form dense stands elsewhere in south-eastern Australia (e.g. Bennett 1994, Benson 1992, Ladiges et al. 1981, Ryan et al. 1996).

Sedgeland

Structure: tall closed sedgeland.

Floristic composition: *Baumea juncea* dominates. *Casuarina glauca* and *Phragmites australis* may be present as scattered emergents.

Habitat and community relations: Found on supratidal flats of the Wallis Lake estuary, and grades into *Juncus kraussii* subsp. *australiensis* rushland at slightly lower elevations. *Baumea juncea* often extends landward as an understorey dominant in *Casuarina glauca* swamp sclerophyll forest and woodland.

Distribution and equivalent vegetation types: *Baumea juncea* sedgeland is present along much of the NSW coast (Adam et al. 1988, Clarke 1993, Griffith et al. 2000, Kratochvil et al. 1973), and it also occurs in Victoria (Head 1988) and south-eastern Queensland (Beadle 1981).

Rushland

Structure: tall closed rushland.

Floristic composition: *Juncus kraussii* subsp. *australiensis* dominates, although *Sporobolus virginicus* may be present as a shorter but continuous species. *Casuarina glauca* can be a scattered emergent.

Habitat and community relations: Extensive on tidal flats of the Wallis Lake estuary, and replaced by *Baumea juncea* sedgeland or *Casuarina glauca* swamp sclerophyll forest and woodland at slightly higher elevations.

Distribution and equivalent vegetation types: *Juncus kraussii* subsp. *australiensis* rushland is widespread on the NSW North Coast, and extends to the Central and South Coasts (Adam et al. 1988, Beadle 1981, Benson 1986, Clarke 1993, Goodrick 1970, Griffith et al. 2000, Kratochvil et al. 1973). It also occurs in south-eastern Queensland (Batianoff & Elsol 1989, Durrington 1977).

Environmental relationships of the Nabiac wallum

Swales, flats and swamps support sedgeland, wet heathland, and the swamp sclerophyll subformations of shrubland, forest and woodland. This vegetation remains floristically distinct from the dry heathland, and dry sclerophyll subformations of mallee woodland, forest and woodland found on beach ridges and dunes (Figure 2), even though the eroded landforms have minimal elevation and degraded relief. Numerical analysis (Figure 2) also identified floristic similarities between different structural formations (e.g. heathland and shrubland), and this trend is consistent with the previous study of wallum by Griffith et al. (2003).

Some stands of shrubland and heathland at Nabiac on the most degraded ridge – swale toposequences support a mix of species from both wet and dry habitats. Ordination confirmed the transitional or ecotonal character of these stands, distinguished using API as either intermediate dry heathland (IDH) or intermediate dry sclerophyll shrubland (IDSS) on the basis of structure (Figure 3).

Axis 1 in Figure 3 is consistent with a moisture gradient linked to topography, separating the driest vegetation on ridges (left of origin) from vegetation of poorly-drained flats and open depressions (near and just right of origin) and also from vegetation tolerant of standing water in closed depressions (further right). When compared with topography, a complex gradient, the singular relationships between floristic composition and each numerical environmental variable (depicted as vectors) were found to be relatively unimportant. The finding that topography is likely to be a primary determinant of vegetation pattern is consistent with previous studies in wallum (Coaldrake 1961, Griffith et al. 2003). Apart from displaying a moisture gradient, the ordination dispersed samples for vegetation formations and subformations represented by more than one API group, suggesting internal floristic heterogeneity. This trend is most evident for the sedgeland formation (S–1, S–2), and also within the swamp sclerophyll forest subformation (SSF–1, SSF–2).

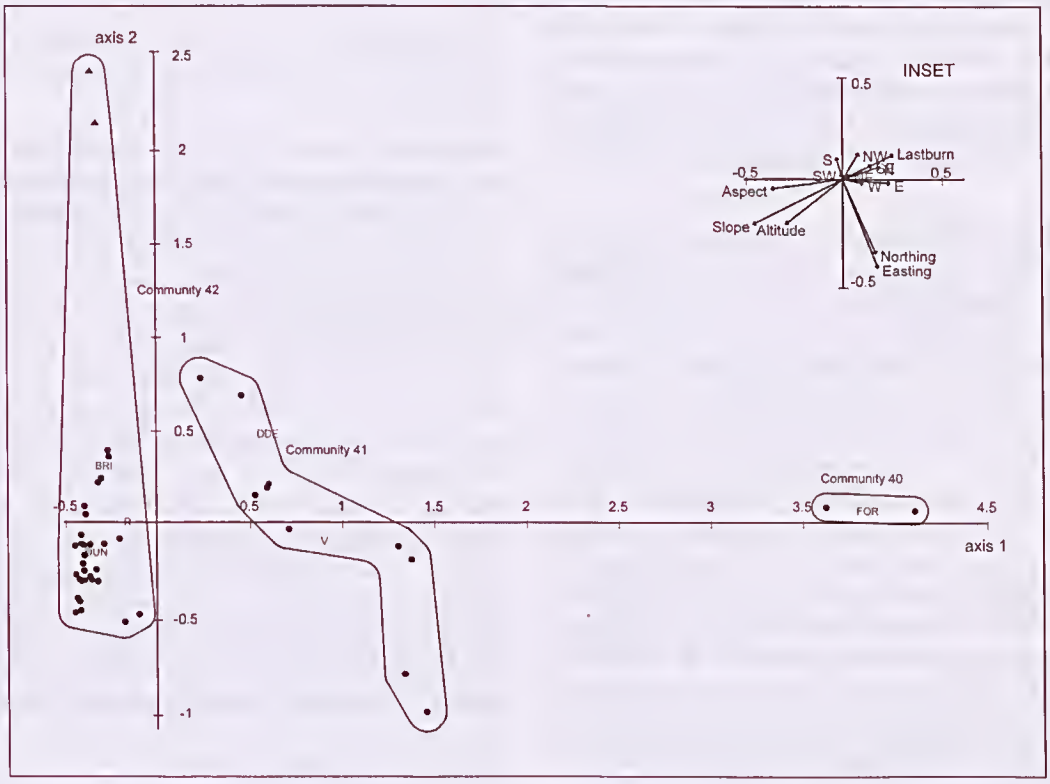


Fig. 4. Ordination of floristic and environmental data for wallum mallee at Nabiac and further north in NSW.

Eigenvalues: axis 1 = 0.7505; axis 2 = 0.3426. Axis 1 is significant ($P < 0.001$). BRI = beach ridge; DDE = drainage depression; DUN = dune; FOR = foredune; V = open depression. Nabiac samples appear as solid triangles. Communities No. 40–42 of Griffith et al. (2003) are: 40 = *Lophostemon confertus* dry sel. mallee; 41 = *Eucalyptus robusta/E. racemosa* subsp. *racemosa* – *Baloskion tetraphyllum* subsp. *meiostachyum* swamp sel. mallee; 42 = *Eucalyptus pilularis/E. planchoniana/E. racemosa* subsp. *racemosa* – *Leptospermum trinervium* dry sel. mallee.

Comparative analysis of the Nabiac wallum

The wallum ecosystem is highly attenuate along the coast of eastern Australia, and floristic composition varies as species reach their northern or southern limit of distribution. Nonetheless, published accounts for occurrences in south-eastern Queensland and other parts of north-eastern NSW suggest similarities with the vegetation at Nabiac (e.g. Clifford & Specht 1979, Coaldrake 1961, Durrington 1977, Griffith et al. 2003, Myerscough & Carolin 1986, Sattler & Williams 1999); and the shrubby vegetation of *Eucalyptus racemosa* subsp. *racemosa*, *Banksia aemula* and associated species that is extensive on the Nabiac barriers is certainly reminiscent of old wallum landscapes found elsewhere (e.g. Thompson & Moore 1984, Walker et al. 1981).

Species on the Nabiac barriers that appear to be absent from wallum further north include *Allocasuarina simulans*, *Callistemon citrinus*, *Lepidosperma limicola* and *Tetratheca ericifolia*. Another group of species including *Acacia quadrilateralis*, *Eucalyptus globoidea* and *Leptospermum arachnoides* are locally abundant at Nabiac but comparatively rare in the ecosystem at lower latitudes in NSW (Griffith et al. 2003). Nonetheless, most of the API groups distinguished at Nabiac for mallee, shrubland, heathland and sedgeland were found to support at least two-thirds of the species in the equivalent communities circumscribed by Griffith et al. (2003) for much of the NSW North Coast between the Manning River and the Lennox Head district. The proportion of shared species is even higher when calculations are adjusted to exclude those restricted to Nabiac.

Griffith et al. (2003) distinguished three mallee communities north of Nabiac: dry sclerophyll mallee shrubland dominated by *Lophostemon confertus* on contemporary foredunes (No. 40, Figure 4); swamp sclerophyll mallee shrubland, mallee forest and mallee woodland dominated by *Eucalyptus robusta* in open depressions, or rarely by *E. racemosa* subsp. *racemosa* on poorly drained dunes with minimal relief (No. 41); and dry sclerophyll mallee shrubland, mallee forest and mallee woodland on comparatively well-drained dunes and beach ridges dominated by varying combinations of *Eucalyptus pilularis*, *E. planchoniana* and *Corymbia gummifera*, or alternatively by *E. racemosa* subsp. *racemosa* as small, disjunct stands (No. 42). Ordination (Figure 4) confirmed similarities between *E. racemosa* subsp. *racemosa* dry sclerophyll mallee woodland on the Nabiac barriers and the equivalent community No. 42 of Griffith et al. (2003), which ranges widely along the coast of north-eastern NSW.

Seven shrublands are recognised for wallum in NSW to the north of Nabiac (Griffith et al. 2003), and an ordination (Figure 5) compares these with the shrubland data for Nabiac. The Nabiac samples for swamp sclerophyll shrubland dominated by *Banksia ericifolia* subsp. *macrantha* (swales) or *Melaleuca sieberi* (flats) align with the comparable community No. 35 of Griffith et al. (2003), which has a tallest stratum dominated by either of these species. *Banksia ericifolia* subsp. *macrantha* dominates in another community (No. 34) circumscribed by Griffith et al. (2003), although this has different species as associates or in the understorey and some do not extend south to Nabiac (e.g. *Leptospermum whitei*). The Nabiac samples for dry sclerophyll shrubland on ridges in which *Banksia aemula* is characteristic align with the equivalent *B. aemula – Phyllota phylicoides* community (No. 32) of Griffith et al. (2003), and this is widespread on the North Coast.

For wallum comprising a single stratum (e.g. heathland, sedgeland), a high degree of congruence can be expected between a vegetation classification based upon API and floristic assemblages derived by numerical classification of foliage cover data (Griffith et al. 2003). An ordination of data for single-stratum wallum at Nabiac and elsewhere in north-eastern NSW preserved the identity of formations and subformations, although also highlighting some overlap in floristic composition between, for example, wet heathland and sedgeland (Figure 6). Also included in the analysis were data for single-stratum vegetation found in clay or loam soils. This vegetation occurs on the slopes and crests of bedrock headlands and coastal hills (graminoid clay heathland, *Themeda australis* sod grassland), or otherwise associates with backbarrier flats and open depressions draining hills (*T. australis – Ptilothrix deusta* tussock grassland, wet heathland).

The Nabiac samples for dry heathland align with those for this subformation along the NSW coast to the north (Figure 6). The Nabiac samples for wet heathland similarly align with equivalent data from further north, and occurrences in swales remain floristically distinct from those on flats associated with plains and backplains (cf. Figure 3). Although included with data from further north, the sedgeland samples for Nabiac are widely dispersed, and this trend reflects floristic variation within the formation. The overlap between wet heathland and sedgeland indicates floristic similarities, particularly between a wet heathland variant in deep peat along swales and an allied sedgeland with abundant *Gahnia sieberiana* (Griffith et al. 2003). The ordination preserves the comparatively strong relationship between floristic composition and topography, although weaker correlations are evident with vectors for some numerical variables (e.g. the positive correlation of sod grassland and graminoid clay heathland with slope and altitude).

Conservation significance.

The Nabiac barriers and associated flats have conservation value for the protection of nationally or regionally significant plants. These include species listed as Endangered (*Allocasuarina defungens*) or Vulnerable (*Allocasuarina simulans*, *Maundia triglochinoides*) under the Threatened Species Conservation (TSC) Act 1995, others at their

distribution limit in wallum around Wallis Lake (e.g. *Banksia ericifolia* subsp. *macrantha* – southern, *Lepidosperma limicola* – northern, *Schoenus scabripes* – southern, *Tetratheca ericifolia* – northern), and also species that are generally rare or uncommon in wallum further north (e.g. *Acacia quadrilateralis*, *Almaleea paludosa*, *Callistemon citrinus*, *Caustis pentandra*, *Eucalyptus piperita*, *Gonocarpus salsoloides*, *Leptospermum arachnoides*, *Symphionema paludosum*). Stands of *Eucalyptus globoidea* forest and *Eucalyptus racemosa* subsp. *racemosa* mallee woodland are also significant at Nabiac – the former is not known from wallum further north in NSW, whereas the latter is apparently uncommon (Griffith et al. 2003).

Vegetation associated with nearby estuarine and alluvial landforms also has known or potential conservation significance. Coastal saltmarsh, for example, is an Endangered Ecological Community under the TSC Act, and this vegetation occurs on tidal flats of the Wallis Lake estuary. Several types of floodplain forest in northern NSW are also listed as Endangered, for example Swamp Oak Floodplain Forest, Sub-tropical Coastal Floodplain Forest and Swamp Sclerophyll Forest on Coastal Floodplains, as described in Keith and Scott (2005). Remnant and regrowth stands of these forests extend east of the Nabiac barriers onto alluvial landforms associated with the Wallamba River floodplain.

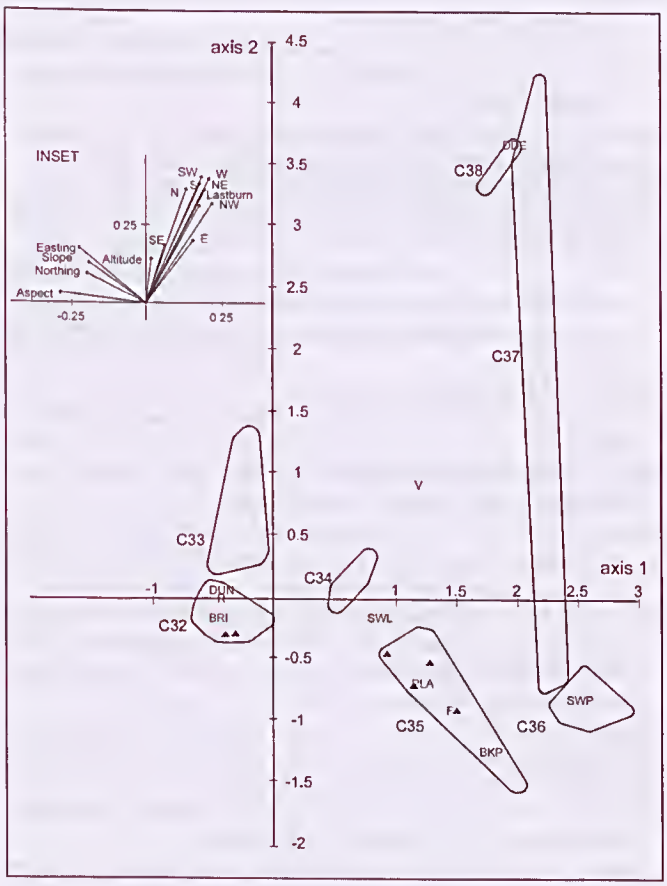


Fig. 5. Ordination of floristic and environmental data for wallum shrubland at Nabiac and further north in NSW.

Eigenvalues: axis 1 = 0.7476; axis 2 = 0.5449. Axis 1 is significant ($P < 0.001$). BKP = backplain (see Methods for details of other centroid codes). The SWP and D centroids coincided (later not shown). Nabiac samples appear as solid triangles. To aid interpretation of the biplot, polygons alone define the distribution of other samples (n = 86). Shrubland communities No. 32–38 of Griffith et al. (2003) are denoted: C32 = *Banksia aemula – Phyllota phylicoides*; C33 = *Banksia aemula – Allocasuarina littoralis* +/- *B. serrata*; C34 = *Banksia ericifolia* subsp. *macrantha* +/- *Leptospermum whitei – L. polygalifolium* subsp. *cismontanum*; C35 = *Melaleuca sieberi/Banksia ericifolia* subsp. *macrantha – M. thymifolia*; C36 = *Melaleuca quinquenervia – Baumea teretifolia*; C37 = *Melaleuca quinquenervia – Baumea juncea*; C38 = *Leptospermum speciosum*.

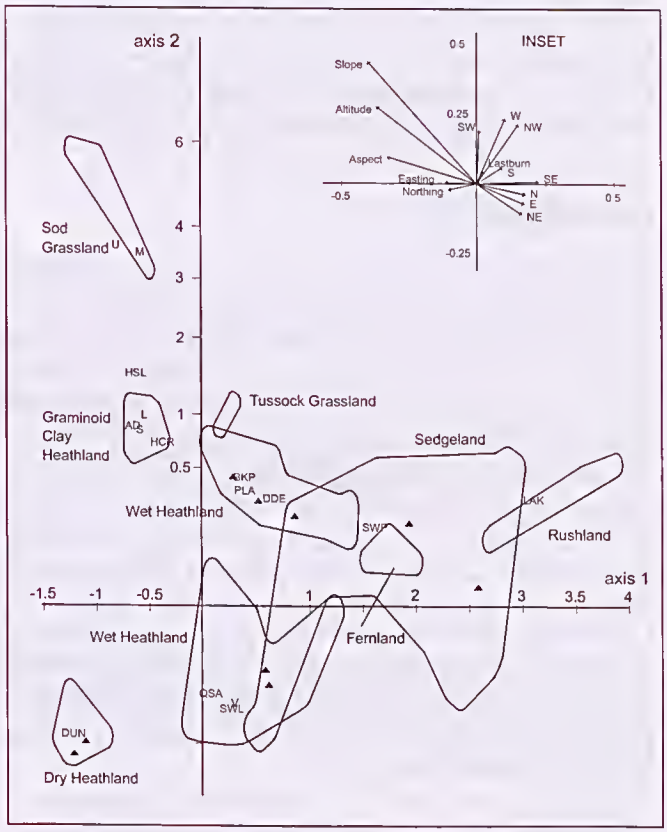


Fig. 6. Ordination of floristic and environmental data for wallum and related vegetation comprising a single stratum at Nabiac and further north in NSW.

Eigenvalues: axis 1 = 0.7344; axis 2 = 0.5777. Axis 1 is significant ($P < 0.001$). AD = adamellite (igneous rock); BKP = backplain; C = crest; HCR = hillcrest; HSL = hillslope; L = lower slope; LAK = lake; M = mid-slope; S = simple slope; SD = sedimentary rock (undifferentiated); U = upper slope (see Methods for details of other centroid codes). Overprinted centroids (in brackets) were omitted from the biplot to aid interpretation: DUN (with BRI and R); HCR (with C); BKP (with F); SWP (with D); HSL (with SD). To further improve interpretation, axis 2 was square root transformed after the ordination, and polygons alone define the distribution of samples (n = 360) in the respective formations and subformations (except

Research initiatives

Dunefields and beach ridge plains are characteristic landform patterns supporting wallum in eastern Australia, and the latter pattern dominates at Nabiac. Despite a long period of exposure to erosion, resulting in minimal elevation and degraded relief, the Nabiac barriers maintain floristic patterns related to topography and hence groundwater relations. From this observation, and another of strong floristic similarities with the ecosystem throughout large parts of its distribution, it is concluded that the Nabiac site is sufficiently representative to confirm its value for research into mechanisms of groundwater utilisation by wallum.

The research project at Nabiac is underway in collaboration with Dr Nigel Warwick (UNE), and this will investigate: (a) root system architecture, thereby identifying potential indicator species of adverse groundwater extraction impacts; (b) root activity and the soil water dynamics that determine this activity; (c) mechanisms of water utilisation; and (d) the role of groundwater in plant nutrition.

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Appendix 1. Foliage cover scores for vascular species in wallum samples at Nabiac

Foliage cover: 0 = absent; 1 = <1%; 2 = 1–5%; 3 = 6–25%; 4 = 26–50%; 5 = 51–75%; 6 = 76–100%. See Figure 2 for details of formations and subformations sampled in quadrats.

Sample locations:

NAB001.1: 32°08'46"S, 152°25'34"E
NAB002.1: 32°08'46"S, 152°25'10"E
NAB003.1: 32°08'55"S, 152°27'13"E
NAB004.1: 32°09'10"S, 152°26'33"E
NAB005.1: 32°09'27"S, 152°27'00"E
NAB006.1: 32°10'25"S, 152°27'15"E
NAB007.1: 32°10'25"S, 152°27'07"E
NAB008.1: 32°07'44"S, 152°25'54"E
NAB009.1: 32°07'39"S, 152°25'45"E
NAB010.1: 32°07'11"S, 152°26'41"E
NAB011.1: 32°07'42"S, 152°26'34"E
NAB012.1: 32°10'34"S, 152°27'31"E
NAB013.1: 32°10'36"S, 152°27'36"E
NAB014.1: 32°10'15"S, 152°26'11"E
NAB015.1: 32°10'05"S, 152°25'48"E
NAB016.1: 32°07'39"S, 152°25'56"E
NAB017.1: 32°07'49"S, 152°25'43"E
NAB018.1: 32°08'49"S, 152°25'09"E
NAB019.1: 32°08'49"S, 152°25'13"E
NAB020.1: 32°09'16"S, 152°26'54"E
NAB021.1: 32°09'51"S, 152°27'17"E
NAB022.1: 32°09'54"S, 152°27'16"E
NAB023.1: 32°10'30"S, 152°27'12"E
NAB024.1: 32°10'52"S, 152°27'10"E
NAB025.1: 32°10'57"S, 152°27'04"E
NAB026.1: 32°11'04"S, 152°27'08"E
NAB027.1: 32°06'49"S, 152°26'58"E

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
Class LYCOPSIDA																											
LYCOPODIACEAE																											
Lycopodiella lateralis	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
SELAGINELLACEAE																											
Selaginella uliginosa	1	0	0	1	2	0	0	0	0	2	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3
Class FILICOPSIDA																											
BLECHNACEAE																											
Blechnum indicum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0
DENNSTAEDTIACEAE																											
Hypolepis muelleri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	1	3	3	0
GLEICHENIACEAE																											
Gleichenia microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	0
LINDSAEACEAE																											
Lindsaea linearis	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCHIZAEACEAE																											
Schizaea bifida	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Class MAGNOLIOPSIDA – LILIIDAE																											
ANTHERICACEAE																											
Caesia parviflora var. *parviflora*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sowerbaea juncea	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARECACEAE																											
Livistona australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
BLANDFORDIACEAE																											
Blandfordia grandiflora	0	0	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
COLCHICACEAE																											
Burchardia umbellata	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CYPERACEAE																											
Baumea articulata	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Baumea teretifolia	1	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
Caustis pentandra	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
CYPERACEAE *cont.*																											
Caustis recurvata var. *recurvata*	0	0	0	0	0	3	0	3	2	0	0	2	1	0	0	2	3	0	0	3	0	0	3	1	0	0	1
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Chorizandra sphaerocephala	3	0	0	3	1	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	1	0	0	0	0	0
Eleocharis sphacelata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0
Gahnia sieberiana	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0
Lepidosperma filiforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma gunnii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma limicola	0	0	0	1	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma longitudinale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Lepidosperma neesii	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma quadrangulatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Ptilothrix deusta	0	0	3	1	4	0	0	0	0	4	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Schoenus brevifolius	2	0	2	1	0	0	0	1	0	2	2	1	1	1	2	0	1	0	3	2	2	2	0	0	0	0	3
Schoenus ericetorum	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Schoenus paludosus	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus scabripes	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus turbinatus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricostularia pauciflora	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HAEMODORACEAE																											
Haemodorum corymbosum	1	0	1	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
IRIDACEAE																											
Patersonia sericea	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Patersonia sp. aff. *fragilis*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUNCAGINACEAE																											
Maundia triglochinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Triglochin procerum s. lat.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Triglochin procerum s. str.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOMANDRACEAE																											
Lomandra glauca	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	1
Lomandra longifolia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0
ORCHIDACEAE																											
Caleana major	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
PHORMIACEAE																											
Dianella caerulea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0
POACEAE																											
Entolasia stricta	2	0	1	1	2	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
Hemarthria uncinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Imperata cylindrica var. *major*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ischaemum australe	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Leersia hexandra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Panicum simile	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Phragmites australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pseudoraphis paradoxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
RESTIONACEAE																											
Baloskion pallens	1	0	0	0	0	0	3	0	1	0	0	0	2	0	1	0	1	0	0	2	0	1	1	0	0	0	1
Baloskion tetraphyllum subsp. *meiostachyum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	4	0
Coleocarya gracilis	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Empodisma minus	0	0	0	4	0	0	0	0	0	0	0	0	0	5	0	0	0	0	3	0	0	0	0	0	0	0	0
Eurychorda complanata	3	0	0	1	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0	3	0	0	0	0	0
Hypolaena fastigiata	0	0	0	0	0	3	0	2	3	0	0	3	0	0	0	2	3	0	0	3	0	0	3	2	2	0	2
Leptocarpus tenax	3	0	3	1	3	0	0	0	0	3	3	0	3	0	2	0	1	0	2	2	0	1	2	0	0	0	0

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
RESTIONACEAE *cont.*																											
Lepyrodia muelleri	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepyrodia scariosa	0	0	0	0	2	0	0	0	0	0	2	0	1	1	1	0	0	0	0	2	0	0	0	0	0	0	3
Lepyrodia sp. A ('*imitans*' ms.)	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sporadanthus caudatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sporadanthus interruptus	0	0	0	1	0	0	0	0	1	0	0	0	0	1	2	0	1	0	0	2	0	1	3	0	0	0	0
SMILACACEAE																											
Smilax glyciphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
XANTHORRHOEACEAE																											
Xanthorrhoea fulva	0	0	0	0	3	0	0	0	0	1	0	0	0	1	2	0	0	0	1	1	0	3	0	0	0	1	0
XYRIDACEAE																											
Xyris gracilis subsp. *gracilis*	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0
Xyris juncea	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xyris operculata	2	0	1	2	3	0	0	0	0	2	2	0	0	2	1	0	0	0	0	0	0	3	0	0	0	0	1
Class MAGNOLIOPSIDA – MAGNOLIIDAE																											
APIACEAE																											
Actinotus helianthi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydrocotyle peduncularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Platysace ericoides	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Xanthosia pilosa	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
CASUARINACEAE																											
Allocasuarina defungens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
Allocasuarina simulans	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CLUSIACEAE																											
Hypericum japonicum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CUNONIACEAE																											
Bauera capitata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DILLENIACEAE																											
Hibbertia acicularis	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0
Hibbertia fasciculata	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1
Hibbertia linearis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Hibbertia obtusifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
DROSERACEAE																											
Drosera binata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Drosera spatulata	0	0	0	1	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
ERICACEAE																											
Astroloma pinifolium	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Brachyloma daphnoides	0	0	0	0	0	2	0	2	2	0	0	1	0	0	0	0	3	0	0	0	1	0	0	1	0	0	0
Brachyloma scortechinii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Epacris microphylla var. *microphylla*	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	0	0
Epacris obtusifolia	0	0	0	1	2	0	0	0	0	1	1	0	0	1	2	0	0	0	0	0	0	2	0	0	0	0	0
Epacris pulchella	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	1	0	0	2	0	0	0	1
Leucopogon deformis	0	0	0	0	0	2	0	0	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leucopogon ericoides	0	0	0	0	0	0	0	2	1	0	0	3	3	0	0	2	0	0	0	0	0	0	0	3	1	0	0
Leucopogon lanceolatus var. *gracilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0
Leucopogon leptospermoides	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	3	0	1	1	3	0	1
Leucopogon virgatus	0	0	0	0	0	2	0	1	1	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	1	0	0
Monotoca elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	1	0	0
Monotoca scoparia	0	0	0	0	0	3	0	2	3	0	0	3	0	0	0	3	3	0	0	2	1	0	1	1	3	0	1
Sprengelia incarnata	0	0	0	1	3	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Sprengelia sprengelioides	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Woollsia pungens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
EUPHORBIACEAE																											
Amperea xiphoclada	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Pseudanthus orientalis	0	0	1	0	0	0	0	1	0	0	1	1	2	0	1	0	1	0	0	1	0	0	1	0	0	0	1
Ricinocarpos pinifolius	0	0	0	0	0	1	0	1	1	0	0	2	0	0	0	1	1	0	0	2	1	0	2	1	1	0	0
FABACEAE – FABOIDEAE																											
Almaleea paludosa	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aotus ericoides	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	1	0	0	0	1	0	0
Bossiaea ensata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Bossiaea heterophylla	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chorizema parviflorum	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia floribunda	0	0	1	0	0	0	0	0	0	2	2	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1
Dillwynia glaberrima	0	0	0	0	0	1	0	2	2	0	0	1	2	0	0	0	2	0	0	2	0	0	2	1	0	0	0
Dillwynia retorta	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	3	1	0	0
Gompholobium glabratum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gompholobium pinnatum	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gompholobium virgatum var. *virgatum*	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0
Hardenbergia violacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Mirbelia rubiifolia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllota phylicoides	0	0	0	0	0	1	0	3	2	0	0	1	0	0	0	0	3	0	0	3	1	0	0	1	1	0	0
Sphaerolobium minus	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerolobium vimineum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FABACEAE - MIMOSOIDEAE																											
Acacia elongata	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0
Acacia longifolia subsp. *longifolia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Acacia quadrilateralis	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0
Acacia suaveolens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
GOODENIACEAE																											
Dampiera stricta	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Goodenia paniculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Goodenia stelligera	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
HALORAGACEAE																											
Gonocarpus micrantlus	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gonocarpus salsoloides	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gonocarpus tetragynus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
LAURACEAE																											
Cassytha glabella forma *glabella*	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1
Cassytha pubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0
LENTIBULARIACEAE																											
Utricularia australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Utricularia gibba	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Utricularia lateriflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
LOGANIACEAE																											
Mitrasacme polymorpha	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
MENYANTHACEAE																											
Villarsia exaltata	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
MYRTACEAE																											
Baeckea diosmifolia	0	0	0	0	0	1	0	2	2	0	0	0	2	0	0	0	1	0	0	0	0	0	3	0	0	0	1
Baeckea imbricata	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0
Callistemon citrinus	0	0	1	1	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0
Callistemon pachyphyllus	0	0	1	2	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Calytrix tetragona	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Corymbia gummifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Darwinia leptantha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	1

	NAB001.1	NAB002.1	NAB003.1	NAB004.1	NAB005.1	NAB006.1	NAB007.1	NAB008.1	NAB009.1	NAB010.1	NAB011.1	NAB012.1	NAB013.1	NAB014.1	NAB015.1	NAB016.1	NAB017.1	NAB018.1	NAB019.1	NAB020.1	NAB021.1	NAB022.1	NAB023.1	NAB024.1	NAB025.1	NAB026.1	NAB027.1
MYRTACEAE *cont.*																											
Eucalyptus globoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Eucalyptus pilularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Eucalyptus racemosa subsp. *racemosa*	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0
Eucalyptus robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	1	1	0	0	0	3	0
Eurycomyrtus ramosissima subsp. *ramosissima*	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	2	0	0	1
Leptospermum arachnoides	0	0	0	0	1	0	0	0	0	1	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum juniperinum	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Leptospermum liversidgei	0	0	0	4	0	0	0	0	0	0	1	0	0	4	1	0	0	0	0	0	0	3	0	0	0	2	0
Leptospermum polygalifolium subsp. *cismontanum*		0	0	1	0	1	0	0	3	2	0	0	3	2	0	3	3	2	0	0	3	3	2	3	1	3	04
Leptospermum semibaccatum	0	0	0	0	0	3	0	4	3	0	0	3	3	0	0	2	4	0	0	4	0	0	3	0	0	0	2
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	3	2	0	0
Melaleuca linariifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0
Melaleuca nodosa	0	0	0	0	0	1	0	3	3	1	1	0	4	0	1	3	1	0	0	3	0	0	3	0	0	0	2
Melaleuca quinquenervia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0
Melaleuca sieberi	0	0	0	0	0	0	0	0	0	3	3	0	0	1	2	0	0	0	3	0	0	1	0	0	0	0	0
Melaleuca thymifolia	2	0	4	0	2	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ochrosperma lineare	0	0	0	0	0	3	0	2	0	0	0	3	3	0	0	1	1	0	0	0	0	0	1	0	0	0	0
PITTOSPORACEAE																											
Billardiera scandens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
PROTEACEAE																											
Banksia aemula	0	0	0	0	0	4	0	3	3	0	0	4	4	0	0	4	3	0	0	3	3	0	3	4	4	0	3
Banksia ericifolia subsp. *macrantha*	1	0	1	1	1	1	0	0	0	1	2	0	0	0	4	0	0	0	0	2	0	3	1	0	0	0	2
Banksia oblongifolia	0	0	4	0	2	0	0	2	0	3	4	0	2	0	3	0	2	0	0	3	0	1	2	0	0	0	2
Banksia robur	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0
Banksia spinulosa var. *collina*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conospermum taxifolium	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	3	0	0	0	0
Hakea teretifolia subsp. *teretifolia*	0	0	1	0	5	0	0	0	0	1	2	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0
Isopogon anemonifolius	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Persoonia lanceolata	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	0	1	0	0	1	0	1	1	0	0	0	1
Persoonia virgata	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Petrophile pulchella	0	0	0	0	0	1	0	1	1	0	1	1	1	0	2	0	1	0	0	1	0	0	1	3	0	0	0
RUTACEAE																											
Boronia falcifolia	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	2
Boronia parviflora	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Boronia pinnata	0	0	0	0	0	0	0	2	1	0	0	2	0	0	0	2	2	0	0	2	2	0	0	0	1	0	0
Eriostemon australasius	0	0	0	0	0	2	0	0	2	0	0	3	0	0	0	2	0	0	0	1	1	0	0	3	2	0	0
Philotheca salsolifolia subsp. *salsolifolia*	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Zieria laxiflora	0	0	0	0	0	1	0	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	1	0	0	1
SANTALACEAE																											
Leptomeria acida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
STACKHOUSIACEAE																											
Stackhousia nuda	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STYLIDIACEAE																											
Stylidium graminifolium	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
THYMELAEACEAE																											
Pimelea linifolia	0	0	1	0	0	0	0	1	1	0	1	1	1	0	1	0	1	0	0	0	0	0	1	0	0	0	0
TREMANDRACEAE																											
Tetratheca ericifolia	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1

Backdrop to encounter: the 1770 landscape of Botany Bay, the plants collected by Banks and Solander and rehabilitation of natural vegetation at Kurnell

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Abstract: The first scientific observations on the flora of eastern Australia were made at Botany Bay in April–May 1770. We discuss the landscapes of Botany Bay and particularly of the historic landing place at Kurnell (lat 34° 00' S, long 151° 13' E) (about 16 km south of central Sydney), as described in the journals of Lieutenant James Cook and Joseph Banks on the *Endeavour* voyage in 1770.

We list 132 plant species that were collected at Botany Bay by Banks and Daniel Solander, the first scientific collections of Australian flora. The list is based on a critical assessment of unpublished lists compiled by authors who had access to the collection of the British Museum (now Natural History Museum), together with species from material at National Herbarium of New South Wales that has not been previously available. The list includes *Bidens pilosa* which has been previously regarded as an introduced species.

In 1770 the Europeans set foot on Aboriginal land of the Dharawal people. Since that time the landscape has been altered in response to a succession of different land-uses; farming and grazing, commemorative tree planting, parkland planting, and pleasure ground and tourist visitation. We describe and reconstruct the 1770 vegetation and landscape features of the Kurnell landing place site, now within Botany Bay National Park, based on primary historical sources and surviving remnants of the landscape, and suggest ways in which the remnants can be rehabilitated and enhanced to protect and focus on the botanical, historical and cultural values of this important place.

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Introduction

In April 1770, the British Navy bark *Endeavour* entered Botany Bay, and Lieutenant James Cook and his crew stepped ashore at a small sandy beach that was, and continues to be, 'country' for the Dharawal people. Once ashore, Cook, the botanists Joseph Banks and Daniel Solander, and others, began eight days of exploration and encounter.

If you visit Kurnell today and try to picture the events and encounters that occurred in the 1770 landscape you may find it difficult. Certainly the landform as Cook saw it is still there, the foreshore, the sandy knolls and the stream of freshwater; it has not been overwhelmed by urban structures as has Governor Phillip's landing site at Sydney Cove. At Kurnell the rocky foreshore and a small sandy beach still exist. But the native vegetation, that was the backdrop to the encounters, and had such an impact on the botanists, is but a faint shadow of its original form. Much of the foreshore area today is mown grass; while the *Banksia* scrub of 1770 has virtually disappeared, replaced by a towering forest of Norfolk Island Pines and Australian rainforest trees introduced during more than a century of tree planting by visiting dignitaries and well-meaning beautification projects. The place is green, neat and tidy, a nice parkland, but what has been lost is the essence of the original landscape, a sense of the landscape of encounter, both botanical and human, that Cook, Banks and Solander found themselves immersed in. Which is sad, because it has certainly been a well-loved site, as indicated by the tree planting and the tidiness!

Yet, if you search carefully you will find some elements of the original vegetation; descendants of some of the plants that astounded the young enthusiastic Banks. Up on the southern sandy knoll is the best place to search, amongst the many weed species that dominate the site. The untrained eye can be tricked by the vegetation here, as it includes gum trees that might seem to be native but are actually Tallowwoods, *Eucalyptus microcorys*, native to the forests of the north coast of NSW, but not to the sandhills of Botany Bay (Benson & Eldershaw 2005).

In order to connect with and understand the events of 1770, and the beginnings of scientific study in eastern Australia, we need to be able to experience some of that landscape of encounter for ourselves. But can we regenerate the native

bushland of this important site? Can we restore the vegetation as it was at the time of the *Endeavour*'s visit? We can certainly restore some of the area, using bush regeneration techniques and additional planting, but what about the remnant *Banksia* scrub that is now overtopped by 10–20 m high exotic Pines. The Pines make the area more like a piece of Norfolk Island, a place never visited by Cook, or perhaps more like a place from *Walking with Dinosaurs*. Should Pines be removed, to reinstate the lower tree height of the original vegetation?

The answer is not simple. Since 1770 there has been more than 200 years of landscape change; Governor Phillip's short stay with the First Fleet in 1788, farming and grazing from 1815 to 1900, holidaying and picnicking from 1900 to the present, and of course the commemoration of Cook's landing and other events, by the ceremonial planting of many of the trees that are now so conspicuous. These are legitimate layers of the history of the site, and an awareness of them will enrich visitor experiences. Indeed an awareness of these layers is essential if we are to appreciate the site as more than nice parkland.

The vegetation, both the natural vegetation remnants and the cultural plantings, reflect the layers of history of the site. We see this as a key factor in interpretation and visitor experience. Fundamental is the identification and selective rehabilitation of the 1770 landscape, reflecting layers of Aboriginal landscape and resource use, the setting for the first encounters and the first powerful impact of Australian ecosystems on European science.

In this paper we describe the vegetation of the 1770 landscape, focusing on Kurnell, based on primary historical sources and surviving remnant vegetation. We compile a list of the plant species that were collected at Botany Bay in 1770 by Banks and Solander, and describe the subsequent impact of their collections on the scientific world. We also suggest ways in which the remnant vegetation at Kurnell can be enhanced and restored to recreate some of the botanical and historical character of this important place. Some of the results of this paper are incorporated into the Botanic Gardens Trust website *The Botany of Botany Bay* www.rbgsyd.nsw.gov.au/information_about_plants/botanical_info/Botany_of_Botany_Bay

Location and geomorphic setting

When the *Endeavour* entered Botany Bay in 1770, the crew first stepped ashore on the south side of the bay, at a place approximately 2 km inland of the rocky headland. The landing site is on the Kurnell Peninsula (lat 34° 00' S, long 151° 13' E), about 16 km south of central Sydney (Fig. 1). The immediate area around the landing site was gazetted as a Public Reserve in 1899 and later known as the Captain Cook Landing Place Historic Site. The landing site is now within Botany Bay National Park, a 500 ha conservation park that includes most of the remaining natural bushland on the Kurnell Peninsula, as well as smaller areas at La Perouse on the northern headland of Botany Bay.

Though the area around the monuments associated with Cook's landing is now largely parkland, with planted trees and mown grass, the greater part of the National Park at Kurnell remains natural bushland. This bushland vegetation is mainly eucalypt woodland and sclerophyllous scrub, and is on sand dunes and Hawkesbury sandstone, with very low nutrient soils and naturally subject to periodic fire (Fig. 2). Several of the plant communities, including Kurnell Dune Forest, Swamp Sclerophyll Forest and Littoral Rainforest, are listed as Endangered Ecological Communities under the NSW *Threatened Species Conservation Act* 1995.

Pre-european Landscapes

Kurnell Peninsula is an unconsolidated sandy isthmus joining Cronulla to the sandstone rock-formed south headland of the Botany Bay entrance. The Peninsula has a complex geomorphic history beginning before the last interglacial. A number of palynological studies based on cores from the large fenlands and peatlands on the Kurnell Peninsula give an idea of the pre-history of the area (Martin 1994).

8000 years ago sea level would have been about 3m below present level, and the western part of the floor of Botany Bay would probably have been Pleistocene low dunes covered by sclerophyll woodland vegetation similar to that of the dunes at Kurnell today (Martin 1994). Pollen analysis from a residual fenland (with *Triglochin, Baumea, Sporadanthus,Villarsia*) near the present Oil Refinery by Martin shows that woodland cover with species of *Encalyptus, Angophora costata, Banksia integrifolia/Banksia serrata* and species of *Allocasuarina* suffered losses about 5000 years ago, when a nearby coastal protobarrier was destabilised by rising sea-level, while rapidly-forming fen peat replaced slowly formed oxygen-depleted fine detritus. Over a 2000 year period woodland partly recovered, despite heavier or more frequent firing coincident with the entry of hunter-gathering aboriginal people. Minor destabilisation of local duneland about 1700 years ago brought fine sand into the fen basin. Dryland plant cover increased after this time but was mainly dominated locally by *Monotoca elliptica/Leptospermum laevigatum* scrub possibly linked to the higher population density, or greater continuity of tenure, of later Aboriginal people after 2000 years ago (Martin 1994).

Aboriginal landuse at the time of Cook's visit

At Kurnell, Cook landed in country of the Gweagal Aboriginal clan. The explorers tried to make contact with the local people but what eventuated was a failure of communication and no proper meeting occurred (Thomas 2003; Nugent 2005). However over the eight days the *Endeavour*'s crew remained in the area, there were many encounters with Aboriginal people and in their journals, Cook and Banks provide descriptions of the appearance of the Aboriginal people and their spears, canoes and huts. They wrote of them as being scattered in small groups, and subsisting mainly on fish and shellfish. Frequent reference is made to their fires,

presumably their eamp and eooking fires. *We saw them go into the woods where they lighted fires about a mile from us*, wrote Banks (on 30th April). On 3rd May Cook notes *There were Six Canoes and Six small fires near the shore, and Muscles roasting upon thim and a few Oysters laying near...* The journals give no indication that the Aboriginal people might have burnt the bush deliberately, nor do they mention any signs of past bushfires. It is assumed that the explorers' perspeetive on the look of the country would be dependent on the how reeently the area had been burnt.

The visit of the *Endeavour* April 1770

The *Endeavour*, commanded by Lieutenant James Cook, had set sail from Greenwich in 1769, with a party of seientists lead by Joseph Banks and Dr Daniel Solander. After observing the transit of Venus at Tahiti, Cook made further explorations in the Paeific, including the eireumnavigation of New Zealand, and then headed west towards the then unknown east coast of Australia. The *Endeavour* entered Botany Bay on 29th April 1770 and *Anchor'd under the South shore about 2 Mile within the entrence in 6 fathoms water,...* During the following days excursions were made to various parts of Botany Bay including Bare Island, the La Perouse peninsula, Cooks River, the mouth of the Georges River and along the eoast towards Cronulla.

The *Endeavour* departed on the 6th May, and sailed northward making several landings on the Queensland coast ineluding a foreed stay of nearly 2 months at the Endeavour River near Cooktown when the ship was severely damaged on a eoral reef.

The Kurnell landscape of 1770

Cook, Banks and Solander landed at Kurnell on the afternoon of the 29th April 1770. The vegetation of the landing site however, is hardly mentioned in either Cooks' or Banks' journals which coneentrate on the initial eneounters with the Aboriginal oeeupants of the site. Fresh water was needed; water from a small hole dug in the sand was inadequate, so a site on the northern side of the Bay was searched, but water here in roek pools was difficult to get. The following morning Cook *sent a party of men a shore in the morning to the place where we first landed to dig holes in the sand by which means and a small stream they found fresh water sufficient to water the ship.*

On the 1st May, after the burial of seaman Forby Sutherland (a sailor who had died of consumption) near the watering plaee, Cook, Banks and Solander *made an excursion into the country which we found deversified with woods, Lawns and Marshes; the woods are free from under wood of every kind and the trees are at such a distance from one a nother that the whole Country or at least great part of it might be cultivated without being oblig'd to cut down a single tree; we found the soil every where except in the Marshes to be a light white sand and produceth a quant[it]y of good grass which grows in little tufts about as big as one can hold in ones hand and pretty close to one another, in this manner the surface of the ground is coated in the woods between the trees...*

I saw some trees that had been cut down by the natives with some sort of blunt instrument and several trees that were barked the bark of which had been cut by the same instrument, in many of the trees, especially the palms, were cut steps about 3 or 4 feet asunder for the conveniency of

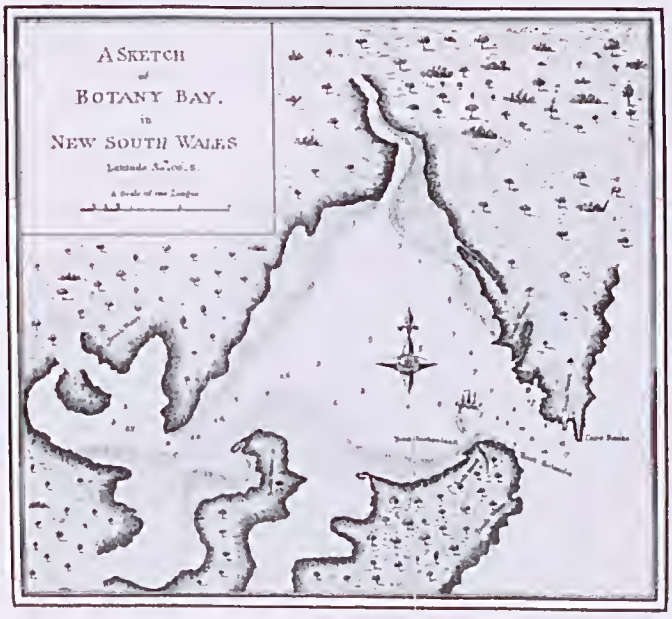


Fig. 1a. James Cook's 1770 map of Botany Bay.

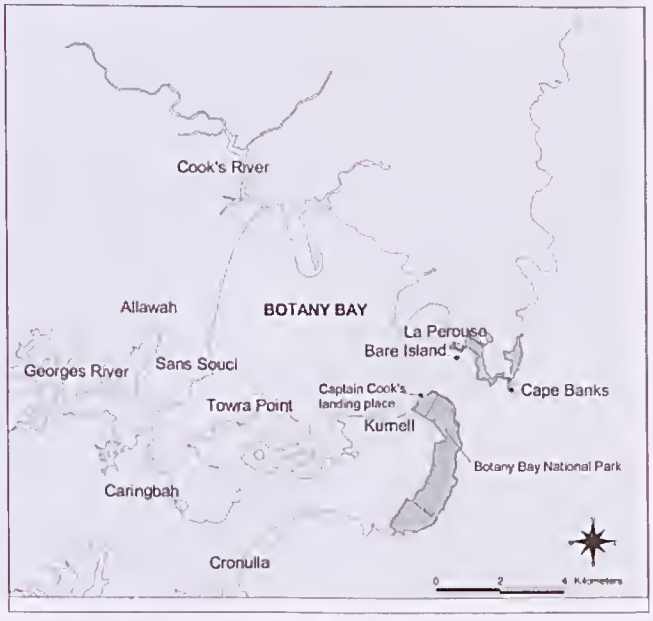


Fig. 1b. Current Locality map showing the Kurnell landing place site and other features around Botany Bay.

climeing them. We found 2 sorts of Gum one sort of which is like Gum Dragon and is the same I suppose Tasman took for gum lac, it is extracted from the largest tree in the woods. (Cook's *Journal*)

The trees that had been "barked", presumably for Aboriginal canoes or shields, could have been rough-barked Eucalypts like *Eucalyptus robusta* or *Eucalyptus botryoides*, or perhaps *Casuarina glauca* or *Avicennia marina*. The palms would have been *Livistona australis* and the *Gum* trees, probably *Corymbia gummifera* or *Angophora costata*.

Banks version of this trip is similar. ...*walkd till we completely tird ourselves, which was in the evening, seeing by the way only one Indian who ran from us as soon as he saw us. The soil wherever we saw it consisted of either swamps or light sandy soil on which grew very few species of trees, one which was large yielding a gum much like sanguis draconis, but every place coverd with vast quantities of grass.* The gum tree he describes was probably the Red Bloodwood *Corymbia gummifera*, of which a specimen was collected at Botany Bay.

The party presumably left the watering place at Kurnell and travelled southwest, somewhere along the route of the present Captain Cook Drive toward Woolooware or Caringbah. They do not mention the sandhills behind Cronulla beach nor the sandstone heath of Endeavour Heights, so they may have kept close to Woolooware Bay, though they do not mention Mangroves either.

Their description of *woods, lawns and marshes*, with the woods free of underwood and open and easily cultivable, together with the accounts of *vast quantities of grass* have always been puzzling. It is likely that the areas they refer to had silty organic soils with areas of swamp forest or woodland. This may have been relatively open with occasional large trees. However areas of true grassland are relatively rare on sandy soils where one would have expected shrubs and sedges to predominate. Grass would be frequent on the clay soils further up the peninsula towards Sutherland, but they surely would have recorded the red coloured clay soils if they had gone that far.

There were evidently grassy areas near the landing place as some of the crew were also occupied as *grasscutters* and *hay cutter* collecting fodder for stock kept on the ship, with Banks recording, on 30th April *Our people went ashore as usual, Dr Solander and myself into the woods. The grasscutters were farthest from the body of the people:* It is not clear what species of grass were being collected.

However grasslike plants or graminoids (in the Sedge or Rush families Cyperaceae, Restionaceae, Juncaceae) would have been abundant in sandy wet places at Kurnell, while in the king-tide and storm-surge zone of the *Casuarina glauca* forest there was probably the grass *Sporobolus virginicus* and possibly *Zoysia macrantha*.

In swamp forest and swamp on similar sandy soil at Myall Lakes, well north of Botany Bay, the only true grasses are *Oplismenus imbecillus* and *Hemarthria uncinata* (Myerscough & Carolin 1986). There are also limited areas of Sand Grassland at Myall Lakes on steep, ocean-facing slopes with grasses including *Themeda australis, Imperata cylindrica* and *Cymbopogon refractus*. In swamp forest at Myall Lakes graminoid species include *Baumea juncea, Baumea rubiginosa, Chorizandra cymbaria, Gahnia clarkei, Gahnia sieberiana, Schoenus brevifolius, Schoenus maschalinus, Empodisma minus, Baloskion tetraphyllus and Juncus continuus*, all of which have also been recorded on the Kurnell Peninsula (Coveny 1960–1980).

It would appear therefore that the *grass* is either sedges or some grassy understorey in swamp forest. There are no grasses on the list of Banks specimens confirmed as being collected at Botany Bay, and the only grasslike species are *Baloskion tetraphyllum, Schoenus ericetorum, Schoenus paludosus* and *Lomandra glauca*. However a number of the Banks' specimens at the National Herbarium of NSW, including 29 grass species, have no indication of where in New Holland they were collected. Nine of these could have been collected at Botany Bay (Table 1).

Other excursions around the Bay: general impressions of the vegetation

During the eight days they spent in Botany Bay, visits and plant collecting were made to various parts of the bay, including Bare Island (Banks 29th April); *the Sea Coast to the south* (Cook, Banks and Solander 3rd May); *the head of the Bay* (Cook, Solander and Munkhouse 3rd May); *ashore on the NW side of the bay* (Banks 4th May); and *the North shore,... 3 or 4 miles into the Country or rather along the Sea Coast* (Cook 5th May).

However there are relatively few references to the vegetation and landscape in Banks' journal which is concerned mainly with descriptions of interactions with the Aboriginal people; his and Solander's botanical descriptions of the specimens collected were recorded separately from the journal entries.

The journal of the *Endeavour* artist, Sydney Parkinson (1773), includes a brief description of the general landscape of Botany Bay with similar comments to those of Banks and Cook,

The country is very level and fertile; the soil, a kind of grey sand; and the climate mild: and though it was the beginning of winter when we arrived, every thing seemed in perfection. There is a variety of flowering shrubs; a tree that yields gum; and a species of palm, [Borasus flabellifer,] the berries of which are of two sorts; one small, eaten by the hogs, and the other, as large as a cherry, has a stone in it; it is of a pale crimson colour, and has the taste of a sweet acid. We also found a species of Salvia Fortea. The palm doubtless refers to the fan palm *Livistona australis*, but the berry, *as large as a cherry* probably refers to the fruit of *Syzygium paniculatum*, which was brought back by Solander (see below). *Salvia Fortea* may refer to *Plectranthus parviflorus*, an herbaceous plant of moist sheltered sites that Banks collected at Botany Bay.

Cook's journal however includes the best landscape descriptions. On 3rd May Cook went with Solander and Dr Munkhouse *to the head of the Bay*, landed and traveled some distance inland. *We found the face of the Country much the same as I have before described but the land much richer, for in stead of sand I found in many places a deep black Soil which we thought was capable of produceing any kind of grain, at present it produceth besides timber as fine meadow as ever was seen. However we found it not all like this, some few places were very rocky but I believe this to be uncommon;*

Where was the head of the Bay? Was it the mouth of the Georges River or the Cooks River? Bertie (1925) argues that it was the Georges River and that the *deep black soil* and *meadow* were near Sans Souci, in the hind-dune swamps later known as Patmores Swamp. Colin Gibson (pers. com. 2006) suggests that they may have landed at the head of Kogarah Bay and traveled inland as far as Allawah or Hurstville, where they would have seen the grassy open-forest on the Wianamatta Shale ridge. The collection of the clay-soil species *Calotis lappulacea* and *Glycine tabacina* could have been made there. However Cook was right that while most of the country was sandy, there were places with better silty alluvial soils. It seems however that Banks subsequently exaggerated their extent in his enthusiastic advice on Botany Bay as a suitable place for settlement.

Cook's *Journal* (6th May) provides a final summary of the landscape of Botany Bay;

altho wood [for fuel] *is here in great plenty yet there is very little variety, the largest trees are as large or larger than our oaks in England and grows a good deal like them and yields a redish gum, the wood itself is heavy hard and black like Lignum Vitae; another sort that grows tall and strait some thing like Pines, the wood of this is hard and Ponderous and something of the nature of American live oaks, these two are all the timber trees I met with. There are a few sorts of shrubs and several Palm trees, and Mangroves about the head of the harbour. The country is woody low and flat as far inland as we could see and I believe that the soil is in general sandy, in the wood are a variety of very boutifull birds such as Cocatoo's, Lorryquets, Parrots &c and Crows exactly like those we have in England. Water fowl are no less plenty about the head of the harbour where there are large flats of sand and Mud on which they seek their food,* ...('large' intertidal sand and mudflats are relatively rare in Botany Bay today)



Fig. 2. Scrub along the sandstone foreshores of Inscription Point in 2006 is still much as it was when the *Endeavour* entered Botany Bay in 1770.

So in Cook's view there were two timber trees (the eucalypts and *Casuarina glauca*), several Palms (*Livistona australis* and presumably the cycad *Macrozamia communis*), Mangroves (presumably *Avicennia marina*, though *Aegiceras corniculatum* also grows in the Bay) and *a few sorts of shrubs*. Banks would have disagreed about this underestimate of the shrubs. By this time he was amassing and processing a huge number of specimens, the result of which was later to persuade Cook to change the name of the bay from Sting-Ray Bay to Botanist Bay and subsequently Botany Bay (Nugent 2005). He also recognised the efforts of the botanists by naming the headlands of Botany Bay, Cape Banks and Point (now Cape) Solander.

The Botany Bay plant specimens

Banks and Solander had certainly collected enthusiastically at Botany Bay. On May 3rd Banks reported *Our collection of plants was now grown so immensly large that it was necessary that some extraordinary care should be taken of them least they should spoil in the books. I therefore devoted this day to that business and carried all the drying paper, near 200 Quires of which the larger part was full, ashore and spreading them upon a sail in the sun kept them in this manner exposd the whole day, often turning them and sometimes turning the Quires in which were plants inside out*. Despite this, the very next day Banks was back again collecting in the bush, *May 4th Myself in the woods botanizing as usual,...*

A definitive list of the plants collected by Banks and Solander at Botany Bay in 1770 was never formally published. What happened?

In July 1771 Banks and Solander returned to London with an immense amount of material, the botanical part of which, for the most part, already had written descriptive tickets drawn up by Solander. Solander took up residence in Banks' house as botanist-librarian. The descriptive tickets were arranged in systematic order, and transcribed for publication, but formal publication was never achieved. Other botanists including Carolus Linnaeaus (the son of Linnaeaus) and Joseph Gaertner, a visiting German botany professor, also had access to the material.

Adding to their botanical descriptions was the artwork of Sydney Parkinson, botanical artist on the *Endeavour*, who produced 280 finished and botanically accurate paintings and over 900 sketches and drawings before his death at sea in 1771. About 700 plates were engraved on copper in folio at Banks' expense, and a few prints or proofs were taken, but they too were not published at the time (Hooker quoted in Maiden 1909).

Solander's death in 1782, Banks' devotion to his duties as President of the Royal Society and his involvement with the King's Garden at Kew, as well as economic recession and the wars with France, all probably contributed to the failure of the work to be completed.

The collections were looked after by the botanist–librarian Jonas Dryander (1748–1810) until 1810, and from then on by the botanist Robert Brown (1773–1858). Upon the death of Banks in 1820, Brown inherited Banks' herbarium, library and papers, together with the instruction that they go to the Trustees of the British Museum upon Brown's death. Brown transferred the collections to the British Museum and in 1827 became the first Keeper of the Botanical Department.

In the meantime Sydney plants were being described by other botanists, from specimens and plants grown from seed sent back by the First Fleet, or Spanish and French expeditions. For example, English botanist Sir James Edward Smith (also a friend of Banks) received specimens from Surgeon-General John White in NSW.

Banks himself was perhaps more influential than his specimens. The site at Botany Bay was chosen for a convict settlement largely on his recommendations (though it was later passed over in favour of Port Jackson), and he corresponded with the first governors and sent out a series of naturalists and horticulturalists to the new colony. Among these was Robert Brown, who sailed as a naturalist aboard the *Investigator*. After 1½ years circumnavigating New Holland he spent 3 months in Port Jackson (Sydney). Brown returned to England in 1805 and spent his time clarifying and describing his vast collection of specimens. Brown's descriptions, based mainly upon his own field observations and specimens, are acknowledged as providing the first systematic account of the Australian flora.

As a result, the specimens collected at Botany Bay by Banks and Solander in 1770 did not play a major role in the subsequent systematic description of the Australian flora, and do not include the large number of taxonomic type specimens that might be expected for a major scientific expedition into new territory. However, material collected by Banks in Botany Bay did provide the type specimen for the iconic genus *Banksia* whose type species, *Banksia serrata*, as well as *Banksia integrifolia* and *Banksia ericifolia*, were described by the younger Linnaeus in 1781 in honour of Banks (George 1981).

Joseph Gaertner's visit to Banks in 1778 led to Banks and Solander's material, or the illustrations based on it, being cited as types for a number of species including *Corymbia gummifera*, *Leptospermum arachnoides*, *Leptospermum laevigatum*, *Leptospermum squarrosum*, *Angophora costata*, *Melaleuca armillaris*, *Melaleuca nodosa*, *Syzygium paniculatum* and *Philydrum lanuginosum*. Most recently, reassessment of *Viola hederacea* complex by Thiele and Prober (2003) has included the description of the new taxon *Viola banksii*, citing Banks' Botany Bay collection as a type. The species is still growing wild at Kurnell near Cook's stream.

The Banks and Solander collection is now held in the British Museum (now the Natural History Museum), but in the late 19th century some duplicate material was donated to other institutions relevant to the *Endeavour* voyage. The

National Herbarium of New South Wales received some 600 specimens. A list of 550 species was published at the time (Maiden 1905), including material from Queensland (labelled variously Bustard Bay, Bay of Inlets, Palm Island and Endeavour River) as well as Botany Bay. The material was broken up as a collection and incorporated into the Herbarium with other material of the same species. As a result, it was not possible to access a complete list of the material until it was again separated out in the 1990s, redetermined with current names, databased and maintained as a separate historical collection.

Listing the plants collected by Banks and Solander at Botany Bay

It is of great interest to know how Botany Bay looked in 1770 and what plants were actually collected there. In researching vegetation patterns in the Sydney district (e.g for publications such as Benson & Howell 1990), we have previously referred to a list entitled *Plants Collected by Banks and Solander at Botany Bay in 1770*. This list was originally appended to *Captain Cooks Landing Place Historic Site Plan of Management* (1975). No author is given, but we have always understood that it was compiled prior to the 1770–1970 Cook Bicentenary by Royal Botanic Gardens Sydney botanist, Don J. McGillivray, *Grevillea* expert and enthusiastic botanical historian (McGillivray circa 1970). It is understood that McGillivray's list was based on material held in the British Museum and accessed when he was botanical liaison officer at Kew in 1969–70) (this view is supported by McGillivray's later co-worker Bob Makinson, pers. com 2005).

Unaware of McGillivray's list, a horticulture student in the UK, Susan Edwards, has recently pointed out the absence of a list of Botany Bay specimens and prepared a list based on specimens in the British Museum (Edwards 2004). Edwards appears to have had access to the same British Museum material available to McGillivray, but has included some additional material. She has not had access to the National Herbarium of NSW material.

Table 1. Species collected by Banks and Solander in 1770 at *Botany Bay* (including Kurnell and La Perouse), based on records at the British Museum (McGillivray, Edwards) and on specimens held in the National Herbarium of NSW.
Record source McG=McGillivray (1969–70), Ed= Edwards 2004, NSW= National Herbarium of NSW. Recent Kurnell records confirm species as native to Botany Bay area. NC= New South Wales North Coast

Species	Family	1770 Botany Bay record source	Recent Kurnell record	Nearest record if not Kurnell
Ferns and gymnosperms				
Blechnum camfieldii	Blechnaceae	NSW	2004	
Blechnum indicum	Blechnaceae	NSW	2004	
Cyclosorus interruptus	Thelypteridaceae	NSW	1917	
Lycopodiella lateralis	Lycopodiaceae	NSW	-	Austinmer
Macrozamia communis	Zamiaceae	NSW	2004	
Pteridium esculentum	Dennstaedtiaceae	NSW	2004	
Dicotyledons				
Acacia longifolia	Fabaceae	McG, Ed, NSW	2004	
Acacia suaveolens	Fabaceae	McG, Ed, NSW	2004	
Acacia terminalis subsp. *terminalis*	Fabaceae	McG, Ed, NSW	-	La Perouse
Acacia ulicifolia	Fabaceae	McG, Ed, NSW	2004	
Actinotus helianthi	Apiaceae	McG,Ed	2004	
Actinotus minor	Apiaceae	Ed	1981	
Allocasuarina distyla	Casuarinaceae	NSW	2004	
Allocasuarina littoralis	Casuarinaceae	Ed, NSW	1977	
Angophora costata	Myrtaceae	NSW	2004	
Aotus ericoides	Fabaceae	McG, Ed, NSW	2004	
Astroloma pinifolium	Ericaceae	NSW	2004	
Atriplex cinerea	Chenopodiaceae	Ed	-	Five Islands
Avicennia marina	Verbenaceae	Cook's jnl	2004	Towra Point, Cooks River
Baeckea imbricata	Myrtaceae	McG, Ed, NSW	2004	
Banksia ericifolia	Proteaceae	McG, Ed, NSW	2004	
Banksia integrifolia	Proteaceae	McG, Ed, NSW	2004	
Banksia serrata	Proteaceae	McG, Ed, NSW	2004	
Banera capitata	Baueraceae	McG,Ed	-	La Perouse
Banera rubioides	Baueraceae	McG,Ed	-	La Perouse
Bidens pilosa	Asteraceae	NSW	2004	
Boronia parviflora	Rutaceae	McG,Ed	1981	
Boronia pinnata	Rutaceae	McG,Ed	-	Rose Bay

Species	Family	1770 Botany Bay record source	Recent Kurnell record	Nearest record if not Kurnell
Bossiaea heterophylla	Fabaceae	MeG,Ed	2004	
Breynia oblongifolia	Euphorbiaceae	NSW	2004	
Callistemon citrinus	Myrtaceae	MeG, Ed, NSW	2004	
Calotis lappulacea	Asteraceae	MeG, Ed, NSW	-	Como, Hurstville
Cassytha pubescens	Lauraceae	NSW see text	1977	
Comesperma ericinum	Polygalaceae	MeG,Ed	1981	
Correa alba	Rutaceae	MeG,Ed	1981	
Correa reflexa	Rutaceae	MeG, Ed, NSW	-	La Perouse
Corymbia gummifera	Myrtaceae	NSW	2004	
Cryptandra amara	Rhamnaceae	MeG, Ed, NSW	1981	
Dampiera stricta	Goodeniaceae	Ed, NSW	1981	
Darwinia fascicularis	Myrtaceae	MeG, Ed	1981	
Desmodium rhytidophyllum	Fabaceae	Ed	1977	
Drosera binata	Droseraceae	MeG,Ed	1981	
Epacris longiflora	Ericaceae	MeG, Ed, NSW	2004	
Epacris microphylla	Ericaceae	MeG, Ed, NSW	1981	
Epaltes australis	Asteraceae	NSW	1977	
Eriostemon buxifolius	Rutaceae	MeG,Ed	1981	
Exocarpos cupressiformis	Santalaceae	MeG,Ed	1977	
Geranium homeanum	Geraniaceae	NSW	2004	
Glossogyne tannensis	Asteraceae	NSW see text	-	Glenfield
Glycine tabacina	Fabaceae	Ed	-	Penshurst
Goodenia ovata	Goodeniaceae	MeG,Ed	1977	
Goodenia paniculata	Goodeniaceae	MeG,Ed	1981	
Grevillea mucronulata	Proteaceae	MeG, Ed, NSW	2004	
Hakea dactyloides	Proteaceae	MeG, Ed, NSW	1981	
Hakea gibbosa	Proteaceae	MeG,Ed	1977	
Hakea teretifolia	Proteaceae	MeG,Ed	1981	
Hardenbergia violacea	Fabaceae	Ed	1977	
Hemigenia purpurea	Lamiaceae	MeG, Ed, NSW	1977	
Hibbertia scandens	Dilleniaceae	MeG,Ed	2004	
Hybanthus monopetalus (filiformis)	Violaceae	MeG,Ed	2004	
Isopogon anemonifolius	Proteaceae	MeG,Ed	1981	
Isopogon anethifolius	Proteaceae	MeG,Ed	1977	
Kennedia rubicunda	Fabaceae	MeG,Ed	2004	
Lambertia formosa	Proteaceae	MeG,Ed	-	La Perouse
Lepidium pseudohyssopifolium	Brassicaceae	NSW see text	-	Five Islands
Leptospermum arachnoides	Myrtaceae	NSW	1981	
Leptospermum juniperinum	Myrtaceae	MeG	1977	
Leptospermum laevigatum	Myrtaceae	NSW	2004	
Leptospermum polygalifolium	Myrtaceae	NSW	1977	
Leptospermum squarrosum	Myrtaceae	MeG, Ed, NSW	1977	
Leptospermum trinervium	Myrtaceae	MeG, Ed, NSW	2004	
Leucopogon ericoides	Ericaceae	MeG, Ed, NSW	2004	
Leucopogon virgatus	Ericaceae	MeG,Ed	-	La Perouse
Lobelia dentata	Lobeliaceae	MeG, Ed	-	Como
Lobelia gracilis	Lobeliaceae	Ed	1907	
Melaleuca armillaris	Myrtaceae	MeG,Ed	2004	
Melaleuca nodosa	Myrtaceae	MeG,Ed	2004	
Melaleuca thymifolia	Myrtaceae	MeG,Ed	1981	
Melanthera biflora [Wedelia]	Asteraceae	Ed	-	Cronulla
Mitrasacme polymorpha	Loganiaceae	Ed, NSW	1977	
Monotoca scoparia	Ericaceae	NSW	1981	
Opercularia aspera	Rubiaceae	MeG, Ed, NSW	1977	
Oxylobium cordifolium	Fabaceae	MeG, Ed, NSW	2004	
Pandorea pandorana	Bignoniaceae	MeG, Ed	1977	
Pelargonium australe	Geraniaceae	NSW	-	La Perouse
Persoonia lanceolata	Proteaceae	MeG, Ed, NSW	2004	
Persoonia levis	Proteaceae	MeG, Ed, NSW	1981	
Petrophile pulchella	Proteaceae	NSW	1981	
Philotheca salsolifolia	Rutaceae	MeG, Ed, NSW	1981	
Pimelea linifolia	Thymelacaceae	MeG,Ed	2004	
Platysace ericoides	Apiaceae	MeG,Ed	1981	
Platysace lanceolata	Apiaceae	MeG,Ed	2004	
Plectranthus parviflorus	Lamiaceae	MeG, Ed, NSW	2004	

Species	Family	1770 Botany Bay record source	Recent Kurnell record	Nearest record if not Kurnell
Pomax umbellata	Apiaceae	McG,Ed	2004	
Poranthera microphylla	Euphorbiaceae	McG,Ed	1977	
Pratia purpurascens	Lobeliaceae	McG,Ed	1977	
Rhagodia candolleana (incl *baccata*)	Chenopodiaceae	McG, Ed, NSW	-	Lady Robinsons Beach
Ricinocarpos pinifolius	Euphorbiaceae	Ed, NSW	2004	
Rumex brownii	Polygonaceae	NSW	1977	
Scaevola calendulacea	Goodeniaceae	Ed	1981	
Scaevola ramosissima	Goodeniaceae	Ed	1977	
Senecio linearifolius	Asteraceae	NSW	-	Ingleburn
Stackhousia viminea	Stackhousiaceae	McG,Ed	-	La Perouse
Stephania japonica	Menispermaceae	NSW	-	La Perouse
Stylidium graminifolium	Stylidiaceae	McG,Ed	1977	
Styphelia viridis	Ericaceae	McG,Ed	1977	
Symphionema paludosum	Proteaceae	McG, Ed, NSW	-	La Perouse
Synoum glandulosum	Meliaceae	McG,Ed	1906	
Syzygium paniculatum	Myrtaceae	Bank's jnl	2006	also Towra Point
Utricularia biloba	Lentibulariaceae	McG,Ed	-	La Perouse
Vernonia cinerea	Asteraceae	NSW see text	1977	
Viola banksii (prev *hederacea*)	Violaceae	McG, Ed, NSW	2004	
Westringia fruticosa	Lamiaceae	McG,Ed	2004	
Woollsia pungens	Ericaceae	McG, Ed, NSW	1981	
Xanthosia pilosa	Apiaceae	McG,Ed	1981	
Xylomelum pyriforme	Proteaceae	McG,Ed	2004	
Zieria pilosa (pinnata)	Rutaceae	McG,Ed	1977	
Monocotyledons				
Baloskion tetraphyllum subsp. *meiostachyus*	Restionaceae	NSW	2004	
Blandfordia nobilis	Blandfordiaceae	McG, Ed	1981	
Commelina cyanea	Commelinaceae	NSW	2004	
Eustrephus latifolius	Philesiaceae	McG,Ed	2004	
Lepidosperma concavum	Cyperaceae	NSW	1981	
Leptocarpus tenax	Restionaceae	NSW	1981	
Livistona australis	Arecaceae	Ed, Cook's jnl	1977	
Lomandra glauca	Lomandraceae	NSW	1981	
Lomandra longifolia	Lomandraceae	McG,Ed	2004	
Patersonia sericea	Iridaceae	Ed	-	Kogarah
Prasophyllum striatum	Orchidaceae	McG,Ed	-	Royal NP
Pterostylis revoluta	Orchidaceae	McG, Ed	1989	
Schoenus ericetorum	Cyperaceae	NSW	1977	
Schoenus paludosus	Cyperaceae	NSW	-	La Perouse
Triglochin procera	Juncaginaceae	McG,Ed	1981	
Grasses that may have been collected from Botany Bay				
Cymbopogon refractus	Poaceae	NSW -no locality	1977	
Digitaria parviflora	Poaceae	NSW -no locality	1977	
Eragrostis brownii	Poaceae	NSW -no locality	1981	
Imperata cylindrica	Poaceae	NSW -no locality	1981	
Oplismenus aemulus	Poaceae	NSW -no locality	1977	
Paspalum vaginatum	Poaceae	NSW -no locality	-	Como, Cooks River, Maroubra
Phragmites australis	Poaceae	NSW -no locality	1977	
Sporobolus virginicus	Poaceae	NSW -no locality	2006	
Themeda australis	Poaceae	NSW -no locality	1981	
Unlikely to be from Botany Bay				
Calandrinia calyptrata	Portulaceae	Ed	-	Ingleburn; Hilltop
Acacia leiocalyx	Fabaceae	Ed		Whale Beach; Qld
Acmella grandiflora	Asteraceae	Ed	-	Lismore; Qld
Wedelia spilanthoides	Asteraceae	Ed	-	NC; Qld
Chamaesyce maegillivrayi	Euphorbiaceae	Ed	-	NC; Qld
Melastoma affine	Melastomataceae	Ed	-	Kempsey; Qld
Drosera indica	Droseraceae	Ed	-	Qld
Cycas media	Zamiaceae	Ed	-	Qld
Acacia legnota?	Fabaceae	Ed	-	
Dodonaea polyandra?	Sapindaceae	Ed	-	

We have therefore combined the recently available NSW herbarium collections for Botany Bay with the lists of McGillivray and Edwards together with a few references to plants in Banks' and Cook's journals (Table 1). Of this list, 80 of the species are common to the British Museum lists of McGillivray and Edwards, with 31 of these also represented in the National Herbarium of NSW specimens. An additional 37 species held in the National Herbarium of NSW can be added to the definitive 1770 list. A further 21 species are listed by Edwards alone and 1 by McGillivray. Of these, 12 have been subsequently recorded in the Botany Bay area, including McGillivray's record of *Leptospermum juniperinum*. The other 10 recorded by Edwards are more likely to have been collected in Queensland or their identification is uncertain. *Lepidium pseudohyssopifolium* is not definitively labeled as being collected at Botany Bay though the specimen at NSW has been annotated by LAS Johnson as being most likely, based on its natural geographic distribution. A similar case applies to *Geranium homeanum*, *Cassytha pubescens* and *Utricularia biloba*.

We conclude with a definitive list of 132 species either collected, or noted by Banks and Solander at Botany Bay in 1770. A list of at least 130 species for eight days collecting in April (not the best flowering time of year) for Botany Bay was not a bad effort. This however is likely to be a minimal list. The list is limited for monocotyledons, only 12 species, and for ferns 5 species. There are no grasses on the list, though the Banks and Solander specimens at NSW include 9 species (Table 1) which could have been collected either at Botany Bay, or in Queensland. No locality is attached. Many plant specimens were collected in North Queensland when the *Endeavour* was repaired near Cooktown, and some specimens are labelled with multiple places (e.g. *Botany Bay, Bustard Bay, Bay of Inlets*).

Were all the collections made at Kurnell?

There are no indications of where particular species were collected around Botany Bay (specimens are at best simply labelled *Botany Bay*), but various day excursions by Cook, Banks or Solander were made to different parts of the Bay. While most of the species listed have been subsequently recorded on the Kurnell Peninsula near the landing place (for example by Coveny 1960–1980, Adam & King 1981), many are relatively widespread in the Sydney area and could have come from many places around the Bay.

A number of species however have narrow habitat requirements and provide evidence for collections at Botany Bay sites other than Kurnell. *Banera capitata*, now a NSW North Coast species, has only ever been recorded in the Sydney area from La Perouse, on the northern side of the Bay (it was last recorded in 1913 and is now extinct there). *Banera rubioides*, though generally more widespread has also been recorded from La Perouse. Neither species has been recorded from Kurnell. These species are likely to have been collected on the La Perouse peninsula.

Other species collected in 1770 and since recorded as occurring at La Perouse, but not Kurnell, are *Lambertia formosa*, *Lencopogon virgatus*, *Stackhousia viminea*, *Utricularia biloba* and *Schoenus paludosus*. These species are likely to have been collected from Eastern Suburbs Banksia Scrub vegetation that is restricted to sand deposits on the northern side of Botany Bay, particularly between Botany and La Perouse. For example on the 4th May, Banks is *ashore on the NW side of the bay, where we went a good way into the countrey which in this place is very sandy and resembles something our Moors in England, as no trees grow upon it but every thing is coverd with a thin brush of plants about as high as the knees.* (Banks'*Journal*). This may have been some of the Eastern Suburbs Banksia scrub near Botany.

Other listed species not subsequently recorded at Kurnell, *Calotis lappulacea*, *Glossogyne tannensis*, *Senecio linearifolius* and probably *Glycine tabacina*, have their nearest known occurrences further inland up the Georges River, particularly at Ingleburn and Glenfield. These are species that generally grow on clay soils such as on the Wianamatta Shale, but may have grown in alluvial forests on the Georges or Cooks Rivers closer to Botany Bay, or on the shale ridgetops near Hurstville, such as was visited by Cook and Solander on 3rd May.

During an excursion to *various parts of the harbour* on 3rd May, Cook and Solander *found also several trees which bore fruit of the Jambosa kind, much in colour and shape resembling cherries. Of these they ate plentifully, and brought home also abundance, which we ate with pleasure, though they had little to recommend them but a slight acid.* writes Banks of presumably, *Syzygium paniculatum*. Presumably this had not been seen near the landing place, although it still grows in the Towra Point part of Botany Bay. As it is cited as a type specimen, a specimen must have been collected, but it has not turned up in our specimen list.

Species which might have been collected on the same excursion are *Rhagodia candolleana*, found on beach dunes, such as on Lady Robinsons Beach and *Lobelia dentata*, a species of sandstone ridges that is conspicuous after fire but not evident in long unburnt sites. It might have been collected in the lower Georges River.

Several other species including *Lepidium pseudohyssopifolium* (now rare, last collected Shellharbour 1949) *Melanthera biflora* and *Atriplex cinerea* (now rare, the 1770 collection is the northern limit) are species of rocky coastal foreshores, and could have been collected along the relatively low level ocean foreshores north from La Perouse.

Melaleuca quinquenervia is currently regarded as reaching its southern geographical limit at Botany Bay. It is certainly native to Rose Bay on Sydney Harbour, but there are no historical collections from further south. Johnson & Briggs regarded the two plants they saw growing at Kurnell in 1965 as native, but there is no confirmed specimen in Banks' collections at Botany Bay (though it was collected

by Banks in Queensland). As three other *Melaleuca* species were recorded at Botany Bay and it was likely to have been fruiting in April–May, its omission is a surprise. Plants at Kurnell may perhaps have been subsequently planted. DNA testing may help confirmation.

Finally *Bidens pilosa* is a most interesting record. This species is currently regarded as an introduced species and is widespread in disturbed sites in eastern Australia. However the identification of it in material from Botany Bay in 1770 (the specimen is in material held in the National Herbarium of NSW) is surely the smoking gun evidence that it is a pre-European occurrence, and therefore should be regarded as a native species. Robert Brown appears to have collected *Bidens pilosa* at Newcastle in 1804 and does not seem to have considered it as introduced (Vallance et at. 2001), while Bentham (1866) could only say *This species is very common as a weed over most warm countries...., and may therefore have been introduced into Australia by cultivation.*

Certainly another case for a bit of DNA work.

Botany Bay in 1788

On the 18th January 1788 the *Supply*, scouting ahead of the First Fleet, entered Botany Bay and anchored on the *Northern side of the Bay, that the Ships which were following might not miss the harbour.* Captain Arthur Phillip explored the foreshores looking for a source of fresh water including going 6 miles up the Cooks River, the country of which he found *low & boggy, & no appearance of fresh water* (P.G. King quoted in King 1982). By the 20th all the 11 ships were in Botany Bay. Searching for a site for a settlement, Phillip found that *the best situation that offered was near Point Sutherland* [Kurnell] *where there was a small run of good water but the ground near it was spongy and the ships could not approach this part of the Bay.* He decided instead to explore Port Jackson to the north, but ordered Major Ross to *have the land cleared* on Point Sutherland, in case he did not find a better harbour. Three days were spent clearing before Phillip returned and the fleet re-embarked for Port Jackson.

Chief Surgeon John White wrote *Although the spot fixed for the town* (i.e. at Kurnell) *was the most eligible that could be chosen, yet I think it would never have answered, the ground around it being sandy, poor and swampy, and but very indifferently supplied with water. The fine meadows talked of in Captain Cook's voyage I could never see, though I took some pains to find them out* (quoted in King 1982)

These early accounts from the First Fleet concur with the earlier descriptions of sandy soils. Cook's descriptions, which are objective with a touch of landscape romance – *diversified with woods, Lawns and Marshes*, and *woods are free from under wood* – are likely to have been an accurate impression. He describes the soil as light white sand producing a quantity of good grass that grows in tufts, presumably that which the grasscutters cut for the livestock. His final comments are that *the soil is in general sandy*. He does not say that the country has great potential for agriculture, though he does suggest that clearing it would be relatively easy. Banks, too, talks about the *swamps or light sandy soils*, and *vast quantities*



Fig. 3. A drawing of Cook's monument by William Henry Raworth in 1875 depicts the dominance of *Banksia integrifolia* in the vegetation surrounding the monument, though when he redraws the scene in 1896, presumably after revisiting the site, the understorey is more open and grassy and the *Xanthorrhoea* has gone.



of grass. However distance perhaps enhanced the view when he advised the British government, years later, on the desirability of Botany Bay as a suitable settlement.

The sandy soils were restricted to the coastal areas and better soils were found on the alluvial and shale soils west of Sydney. The floodplains of the Hawkesbury River and the grassy woodlands of the Cumberland Plain provided the neeessary agricultural base for development of the early colony (Benson & Howell 1990).

Phillip has the last word. After describing the success of agriculture at Rose Hill near Parramatta in a letter to Lord Sydney (12th February 1790) he writes, *And I presume the meadows mentioned in Captains Cook's voyage were seen from the high grounds about Botany Bay, and from whence they appear well to the eye; but when examined are found to be marshes, the draining of which would be a work of time, and not to be attempted by the first settlers.*

Landscape change from 1788

From 1770 until 1815 the area around the landing plaee remained relatively undisturbed and would have eontinued to provide good resourees for loeal Aboriginal people. In 1815, 700 aercs of land at Kurnell was granted to James Birnie who established Alpha Farm, named so because it was the first farm in the area. He ereeted a stone cottage on a foreshore knoll just east of the present Cook Monument site. Over the next 80 years various agricultural enterprises were pursued on the site, gencrally with little success (Nugent 2005).

In 1881, following a succession of landowners, the property became part of the Holt-Sutherland Estate and subsequently subdivided. In 1899, 25 ha near the landing place was dedicated as publie reserve and placed in the care of the Captain Cook Landing Place Trust. The Trust began various 'improvements' on the site and in the early days they eontinued to allow grazing of eattle and horses. In 1902 a guesthouse was built on the site of the old Alpha Farm cottage, ineorporating the ruins of its cellar. With the management of the site as a public reserve, began a new period of signifieant impact on the landscape and vegetation of the site.

Perhaps the greatest long-term impacts of the Trust were the modifieations to natural drainage systems and the changes to vegetation eommunities. The Trust regularly reported on drainage problems in the reserve and invested substantial efforts to reetify problems, including installing metres of underground drains. Most significantly affected was the freshwater stream where the crew of the *Endeavour* took water (Fig. 7). The stream has been diverted into an underground pipe for much of its length, has been dammed at various points, and the swamp that supplied it with water has been substantially modified by road works. In addition to the impaets on the stream's hydrology, the natural riparian vegetation has been virtually eliminated. Few clues remain to its original form and composition. Many of the surrounding areas of swamp forest were also impacted by drainage works, no longer able to support their natural vegetation eommunities.

In 1845 two Norfolk Island Pine trees (*Araucaria heterophylla*) were planted in front of Alpha Farm house. These were the earliest reeorded non-local trees planted at the site (Fig. 4a). Together with the Prinee's Pines planted in 1881, they paved the way for an extensive tree planting program carried out by the Captain Cook's Landing Plaee Trust from 1899 until 1975 (CCLP Trust records). During the years of management

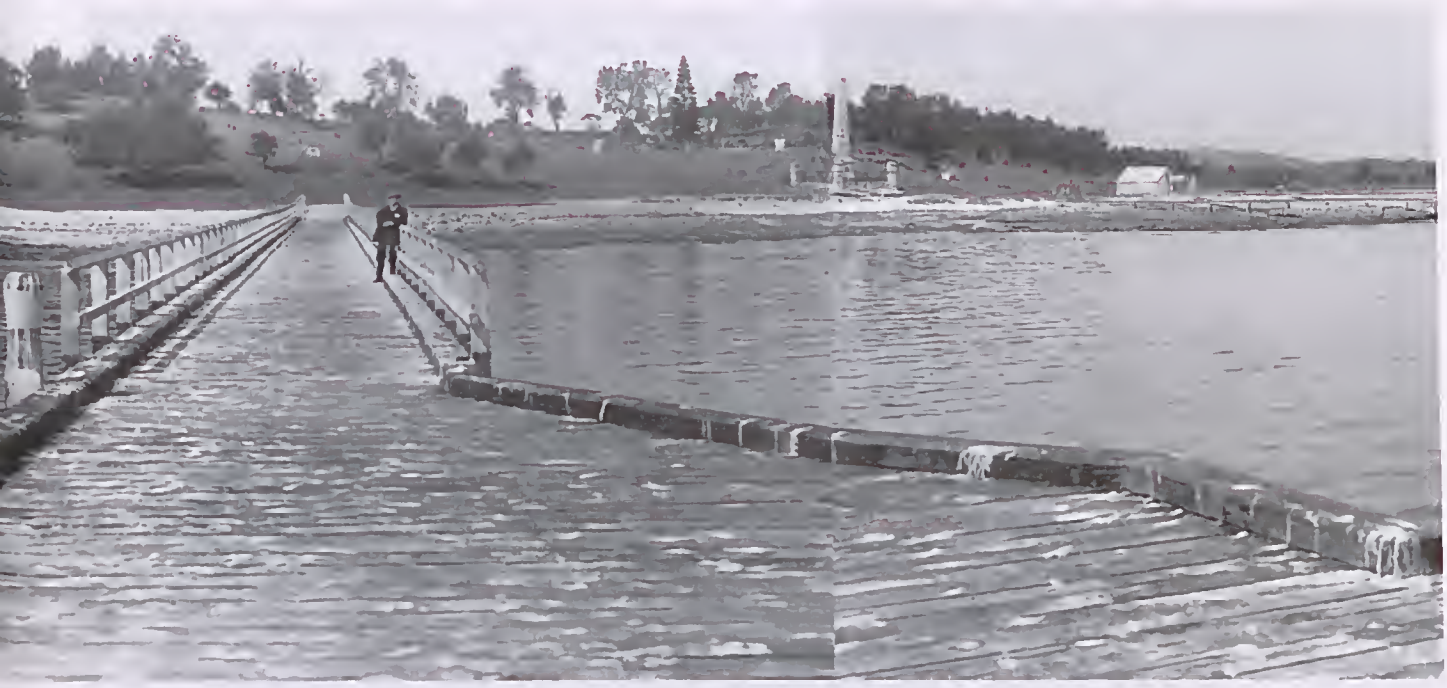


Fig. 4a. Photographs taken in the period 1880 to 1910 show grassy areas around Cook's monument with native low scrub and *Banksia integrifolia,* most no taller than about 8 m, but some taller single-stemmed *Banksia* plants 10–12 m high, a number with deteriorating canopies. This view was taken from the ferry wharf in 1905. Alpha House and the 1845 Norfolk Island Pines are on the far left, and the 1881 Prince's Pine is behind Cook's monument.



Fig. 4b. Similar view above, taken in 2005 showing predominance of planted *Araucaria* trees. The shed marks the site of the old ferry wharf.

Table 2. Summary of the likely main composition of 1770 plant communities of Cook's landing site, Kurnell, with brief comments on the condition in 2006 (introduced species marked*). For full species lists see Appendix 1.

Plant community	Main canopy species likely in 1770	Ground species likely in 1770	Condition in 2006
1. Coastal Scrub/ woodland on sand knolls	*Banksia integrifolia*, *Monotoca elliptica*	*Acacia ulicifolia*, *Kennedia rubicunda*, *Notelaea longifolia*	Many weeds **Asparagus aethiopicus* **Stenotaphrum secundum* **Eucalyptus microcorys* **Ehrecta erecta*, part of Kurnell Dune Forest EEC)
2. Littoral rainforest	*Cupaniopsis anacardioides*, *Livistona australis*, *Syzygium paniculatum*, *Glochidion ferdinandi*	*Viola banksii* *Hypolepis muelleri* *Calochlaena dubia*	Many planted exotics
3. Swamp Forest	*Casuarina glauca*, *Eucalyptus robusta*, *Ficus rubiginosa*	*Commelina cyanea*, *Hydrocotyle peduncularis*, *Marsdenia rostrata*, *Oplismenus aemulus*, *Smilax glyciphylla*, *Pteridium esculentum*	Very small remnants only. Has largely been replaced with mown grassland. Weeds include: **Hydrocotyle bonariensis.* (part of Swamp Selerophyll Forest EEC)
4. Dune woodland	*Eucalyptus botryoides*, *Corymbia gummifera*	*Xylomelum pyriforme*, *Dodonaea triquetra*, *Hibbertia scandens*, *Lepidosperma laterale*	Largely in good condition, except road edges and areas of planted exotics. (part of Kurnell Dune Forest EEC)
5. Sedge-swamp		*Baloskion tetraphyllum*, *Callistemon citrinus*, *Gleichenia dicarpa*, *Blechnum* spp,	Greatly disturbed by drainage changes. Increased spread of drier species such as *Corymbia gummifera*. Weeds include **Lantana camara*
6. Scrub on Sandstone	*Angophora costata*, *Eucalyptus haemastoma*	*Acacia ulicifolia*, *Kunzea ambigua*, *Melaleuca nodosa*, *Allocasuarina distyla*, *Leucopogon ericoides*, *Pteridium esculentum*	Largely in good condition, except road edges.
7. Foreshore scrub on sand	*Leptospermum laevigatum*, *Acacia longifolia* subsp. *sophorae*, *Banksia integrifolia*, *Casuarina glauca*	*Isolepis nodosa*, *Stephania japonica* *Commelina cyanea*, *Lomandra longifolia*	Sandy foreshore scrub now replaced by mown lawn particularly **Stenotaphrum secundatum* Buffalo grass.
8. Foreshore scrub on sandstone	*Banksia integrifolia*, *Westringia fruticosa*, *Melaleuca armillaris*	*Lomandra longifolia*, *Isolepis nodosa*, *Stephania japonica* *Commelina cyanea*	Sandstone scrub still remains on Inscription Point.

by the Trust, significant events, such as the anniversary of Cook's landing and his birth, were commemorated with tree plantings. In addition, the Trust carried out an annual tree planting program aimed at beautifying the site and restoring areas of bush ravaged by bushfire and gales.

The planting programs and drainage modifications, together with the history of relatively intensive land use, have had a major effect on the native vegetation of the site. Extensive areas were cleared for grazing and many of these now correspond to areas of mown exotic grass. Not only was the native vegetation directly affected by tree planting, but also by weed invasion including naturalizations from the plantings. In addition, particularly in the last few decades, many areas have been protected from fire, decreasing the abundance of native species which rely on open conditions and heat for seedling recruitment, whilst benefiting weed species. Cessation of mowing in some areas within the last decade has not resulted in a significant increase in native species arising from the soil-stored seedbank or rootstock, probably because these species had already gone many years earlier during the intensive grazing periods.

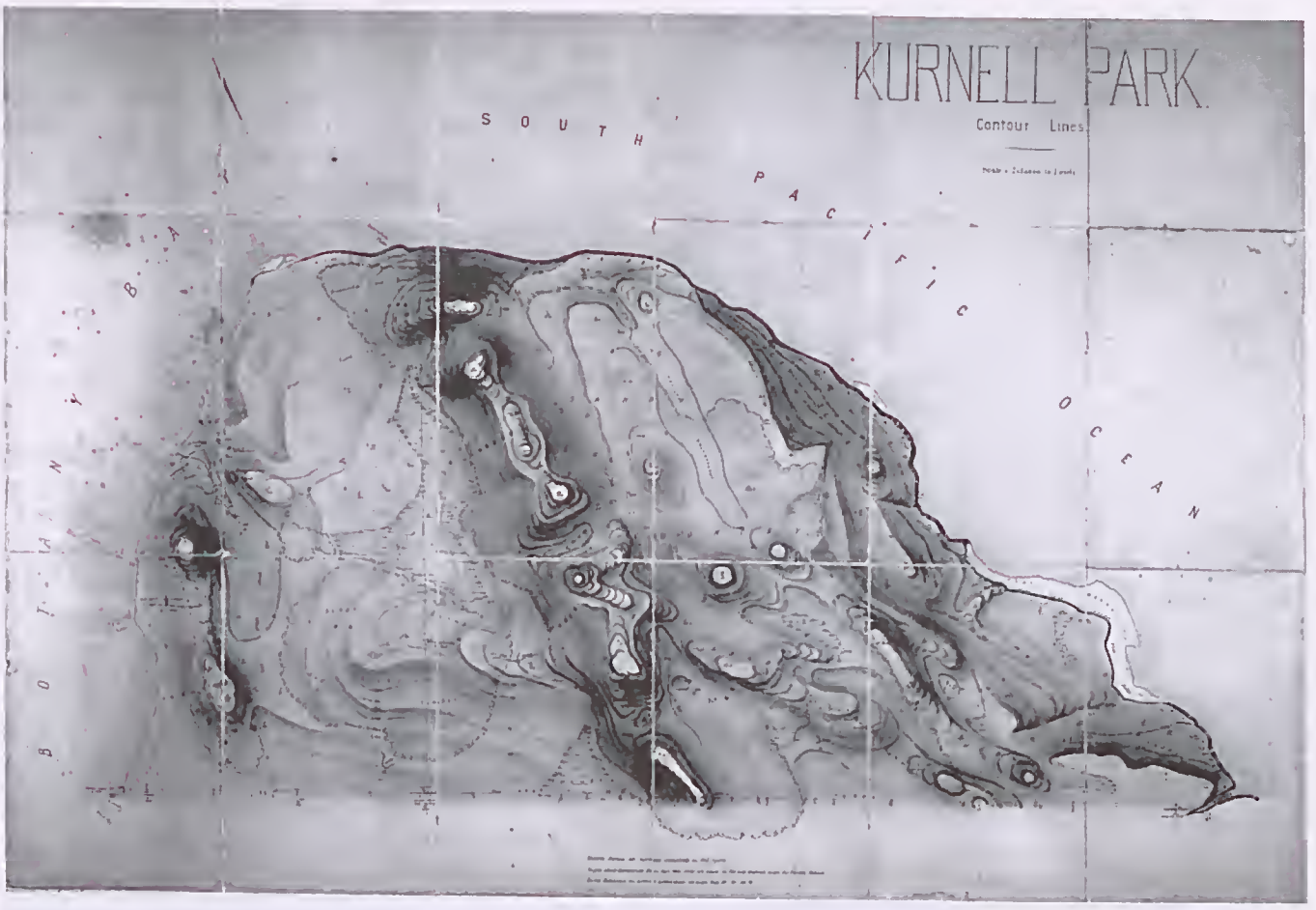


Fig. 5. 1899 Department of Lands plan of "Kurnell Park" showing contours and geographieal features at that time. The Landing Plaee, ferry wharf and sandy knolls are on the far left.



Fig. 6. 1914 view from the southern knoll looking west showing *Banksia – Monotoca* serub in the foreground and grazed grassland along the immediate foreshore. There is serub along the foreshore beyond the fenee near the houses. The picture is from a contemporary land sale broehure.

The pre-European vegetation of the landing place at Kurnell

Despite landscape change and modification of the natural vegetation, the site today still contains remnants of the vegetation that Cook and Banks would have seen in 1770. We have used these remnants, together with historical documentation, such as park plans and aerial and ground photos, to reconstruct the pre-European vegetation communities in the area corresponding to "Cook's Landing Place", the public reserve declared in 1899. Within this 30 hectare site, the likely extent of 1770 plant communities has been inferred (Table 2, Fig. 8a, b) from geological and topographic features using stereoscopic air photo coverage, and historic maps including a detailed 1899 Lands Dept survey which includes notes on vegetation. We have also walked extensively throughout the site noting current species distributions. Notes on individual communities are given below and a current species list is included at Appendix 1.

1. Coastal Scrub/woodland of Banksia integrifolia, Monotoca elliptica on sand knolls

Apart from descriptions in the journals of Cook and Banks, and the specimens they brought back to London, the earliest recorded clues to the natural vegetation of the site are early illustrations of the Cook's monument, erected in 1870. An 1878 watercolour of the monument by Thomas George Glover (National Library of Australia) shows a few scattered trees on a dune behind the monument. The form of the trees strongly suggests *Banksia integrifolia*, but artistic licence has allowed the bushland to be over-simplified and the scene romantically egyptianised. A more realistic 1875 drawing (Fig. 3) by William Henry Raworth (1820–1905) depicts the dominance of *Banksia integrifolia* in the vegetation surrounding the monument, though when he redraws the scene in 1896, presumably after revisiting the site, the understorey is more open and grassy and the *Xanthorrhoea* has gone.

Photographs taken between 1880 and 1910 (eg. Fig 4a) show grassy areas around the monument, with low scrub. There are *Banksia integrifolia* plants, most no taller than about 8 m, but some taller single-stemmed plants 10–12 m high. There are a number with deteriorating canopies. There also appear to be some eucalypts that may be *Eucalyptus botryoides*, and some dead trees. The introduced Princes Pine (planted 1881) is already overtopping the native trees. There appears to be the affects of stock browsing up to about 2 m from the ground. The groundlayer is grassy and evidently heavily grazed and there are some scattered low shrubs, possibly *Monotoca*. One photo shows extensive areas with inflorescences that are probably the grass *Cymbopogon refractus*, Barbed Wire Grass. According to Maiden (1909), locals at Kurnell called this plant *Banks' Orchid*, suggesting it was relatively conspicuous at that time (1909). Several trees of *Banksia integrifolia* were evidently planted within the railing of the monument and these may have been taken from nearby. Compare the original canopy height with the currently towering *Araucaria*-dominated skyline (Fig. 4b).

A detailed 1899 Department of Lands plan of the Landing Place site (Fig. 5) showing contours and geographical features such as rocky areas, gives an overall view of the landscape. The creek is shown as fresh water and is not dammed. Areas of vegetation and open grass land are shown. The two knolls and the connecting saddle adjacent to Cooks Monument are marked 'Sandy ridge covered with Beech Honeysuckle and Scrub'. 'Honeysuckle' would be *Banksia integrifolia* while 'Beech' was a name used for *Monotoca elliptica* (Maiden 1889). Similar 'Honeysuckle and scrub' is shown on a sand hill behind Inseription Point.

From this historical evidence, particularly the late 19th century photos and maps, it would appear that the pre-european vegetation of the sandy northern and southern knolls near Cook's Monument was dominated by small trees of *Banksia integrifolia* and *Monotoca elliptica* with a dense shrubby understorey. We suggest this community was also found on the sandy knoll where Alpha House now stands and on the knoll above Inscription Point. The structure of this community probably ranged from woodland to scrub, depending on the degree of exposure to salt laden winds, and would have contained many of the species of the dune forest of the deeper inland sand areas but the predominance of the *Banksia* and *Monotoca* would have given it quite a different look.

By 1933 A.G. Alanson was writing, *To-day much of the scrub has gone, but banksias and some apple gums remain well grown, while there towers above the low forest a pine planted there, August 9, 1881, by late Prince Albert Victor of Wales, brother of King George V. ... The Princes each planted two trees, but three died*. The *apple gums* were probably *Angophora costata*.



Fig. 7. Photo at the dam on Cook's stream (the Watering Place) in 1910 showing *Casuarina glauca* where it meets Botany Bay. Note: wooden tree-guards to protect planted trees from stock.



Fig. 8a. Contour map of the Landing Plaee site based on 1899 survey, contour interval in metres.



Fig. 8b. The likely extent of plant communities in 1770 at the, Landing Place inferred from geological and topographie features. Despite the extent of vegetation eover shown in this 2004 photo, much of it is planted rather than native vegetation.



Fig. 9. Engraving of Alpha Farm (by H G MacLeod) after about 1870.

Today this community is in a relatively poor state due to grazing, mowing and clearing, weed invasion, particularly of *Asparagus aethiopicus*, the absence of fire which would promote germination of native species, the planting of exotic species such as the Norfolk Island Pine and the planting and subsequent naturalising of non-local native species particularly Tallowwood trees, *Eucalyptus microcorys*. These tree plantings have reduced light to the lower growing shrub species, provided perches for birds dispersing weeds seeds, and have destroyed the appearance of the low-growing scrub/woodland, which would probably have been about 3–8 m high (see Fig. 6), by providing a towering canopy 20–25 m tall. Despite the poor condition of the community, remnant species provide evidence to help us in developing a picture of the structure and content of the original community. The west-facing slope of the southern knoll is the best place to find remnant species, including *Banksia integrifolia, Monotoca elliptica, Clerodendrum tomentosum, Elaeocarpus reticulatus, Notelaea longifolia, Dianella* sp., *Lomandra longifolia, Imperata cylindrica* and *Eustreptus latifolius*. The extent of the original community corresponds to 6.6 hectares of the 30 hectares declared a public reserve in 1899 (Fig. 8).

2. Littoral rainforest – Cupaniopsis anacardioides

Today along Cook's Stream is a vegetation community that displays the structure and indicative species of littoral rainforest. But unlike other areas of the site there are few remnants and little historical evidence to guide our assessment of the original nature of this plant community. The 1899 map (Fig. 5) shows this area substantially free of vegetation with only a small clump of "Oaks" (*Casuarina glauca*) just to the south west of Alpha House. Early 20th century photos at the mouth of the stream (the Watering Place) show *Banksia integrifolia* and *Casuarina glauca* as the dominant species (Fig. 7), but there are no photos of areas further upstream.

On the western side of the creek there is now a woodland canopy with a grassy (exotic) understorey. Most of the trees on the east-facing slope to the creek and up onto the northern knoll are rainforest species, with *Cupaniopsis anacardioides* as the most common, but also present are *Castanospermum australe, Syncarpia glomulifera, Lophostemon confertus* and *Podocarpus elatus* and other obviously introduced and planted species. Of the species present, *Cupaniopsis* is clearly native to the site. There are records of *Cupaniopsis* from Kurnell from the early 20th century, though a specimen was collected by Banks in 1770 is not labeled as whether it came from Botany Bay or Queensland. *Cupaniopsis* is a common component of littoral rainforest in the Sydney area and there are remnant trees elsewhere on the Kurnell Peninsula (including a number of stands of large ones along Silver Beach and Bonna Point – some have the structure and composition of Littoral rainforest – P. Adam pers. com. 2006). However though there are no records of *Cupaniopsis* being planted, the spacing and general size of the trees, together with the lack of any other associated remnant vegetation such as vines, suggests that these are planted trees.

The exotic grassy groundcover also suggests that the area was formerly cleared, and grazed or mowed. Rather than a rainforest community, we therefore suggest the northern knoll originally displayed similar Coastal scrub/woodland to the southern knoll.

However the sandy coastal creekline site is not inconsistent with littoral rainforest habitat in other parts of coastal NSW, and there may have originally been littoral rainforest associated closely with the stream. There are old trees of *Livistona australis* (an indicator species of littoral rainforest) beside the creek now, although historical records suggest some of these may have been planted (CCLP Trust records). However to further complicate the assessment, Cook noted in his journal that he had seen palms that had Aboriginal footholds cut in them. Similarly old trees of *Syzygium paniculatum* near the creek are consistent with the littoral rainforest habitat. In terms of conservation our best position would be to infer an original occurrence of littoral rainforest associated closely with Cook's stream, with Swamp Forest on adjacent alluvial soil, and restore or rehabilitate appropriately.

3. Swamp Forest – Eucalyptus robusta, Casuarina glauca

This community is the most enigmatic. A swamp forest or woodland with large trees of *Eucalyptus robusta* and a grassy understorey would fit with Cook's accounts to some extent and would provide better grazing than the other communities. The main picnic area today (Commemoration Flat) is shown on the 1899 map as *gentle sloping open grass land* with *good black soil* on the foreshore. It is possible that the grassy areas associated with the landing site picnic areas could have been derived from swamp forest vegetation by a century of low-level cattle grazing, the gradual removal of old trees for timber and firewood, tree death from cattle debarking or just old age, alteration of natural drainage systems, and the lack of replacement tree recruitment because of grazing and trampling of seedlings. In some areas tree cover may have been very sparse and the areas may have been virtually grassland.

Given that a land grant was made as early as 1815, and a substantial cottage established soon after, suggests that there is likely to have been some reasonable natural grazing land for stock in the immediate vicinity, though perhaps only for a subsistence lifestyle. In the 1850s John Laycock evidently ran the farm as a dairy and an engraving (Fig. 9), done after 1870, shows the cottage evidently occupied, and 6 dairy cattle and 8 sheep on grassy foreshores. The grazing land is unlikely to have been on the sandstone plateaus or the sandy swamps, but there may have been understorey in the swamp forest associated with peaty soils – Cook's *Lawns and woodlands* – that provided some fodder for stock.



Fig. 10. 1914 panorama looking northeast from near current entrance to Reserve showing the southern knoll. After years of grazing the foreshore flat is completely grassy, though the dune, and sandstone country on the right of the picture, still retain patches of shrubs.

Cattle continued to graze the site under licence from the Captain Cook Landing Pace Trust, until at least 1911 (Fig. 10). The native grassy understorey of the swamp forest would not have stood up to the grazing, draining of the sand and subsequent mowing, and today the grassy areas are of exotic species. Native understorey species in this community might have been *Oplismenus imbecillus, Microlaena stipoides, Imperata cylindrica, Hemarthria uncinata, Phragmites australis, Cymbopogon refractus* and the herbs *Commelina cyanea, Persicaria decipiens, Centella asiatica* and *Viola banksii*.

J. H. Maiden comments that when he was making a list of plants from Kurnell around 1900 (Maiden 1909), *I was amused to find that around Kurnell the grass Andropogon* [now *Cymbopogon*] *refractus, is known as 'Banks' orchid'*! Maiden's list of Kurnell plants does not seem to have survived.

Johnson & Briggs (1965) describe a small area of forest on the Kurnell Peninsula on land to the east of Cooks Stream. *Small but very interesting area, a hanging flat above the bay, sheltered by high land to east, high water-table, carrying a semi-swamp forest of E. robusta and 2 trees only of Melaleuca quinquenervia (southern limit, very important to preserve).*

Banks does not appear to have collected any specimens of *Melaleuca quinquenervia* although he collected 3 other *Melaleuca* species, and as *Melaleuca quinquenervia* is likely to have been in flower, or at least just finishing, in April we could reasonably expect that this species would have been collected, had he come across it.

We have inferred that this community occupied about 11 hectares of the landing place reserve (Fig. 8), concurrent with low-lying areas overlaying sandstone. Remnants of this community are generally in poor condition and their extent is limited. The dominant pressure on this community has been the continual removal of the understorey initially by grazing followed by regular mowing. Swamp forest is consistent with the TSC Act listed Endangered Ecological Community Swamp sclerophyll forest.

4. Dune woodland dominated by Eucalyptus botryoides

On deeper sand away from the foreshores, we find dune woodland intergrading with coastal scrub on stabilised transgressive dunes. This community has been less impacted by grazing and early park management activities, and has been subject to frequent fires. The remnants are in good condition and provide the key evidence for the pre-1770 structure and composition of this community.

This community is part of the TSC Act listed Endangered Ecological Community Kurnell Dune Forest. While this community is extensive to the east of the original landing place reserve, it occupies less than a hectare of the original reserve (Fig. 8).



Fig. 11. Treeless sedgeswamp and wet scrub along the track to Kurnell in 1927.

5. Sedge-swamp

The 1899 park plans clearly show an area of swamp in the upper reaches of Cooks Stream. The plans give no indication of species composition and there are no early photographs of this community. Small remnants of the community can be found along Cape Solander Drive near the Discovery Centre, although the extent and nature of the swamp was substantially impacted by the construction of the tourist road in the late 1960s. The understorey in this community includes *Gahnia sieberana, Calochlaena dubia, Baloskion tetraphyllum* subsp. *meiostachys, Blechnum cartilagineum, Gleichenia dicarpa, Hibbertia scandens* and *Pteridium esculentum*. In the shrub layer and canopy we find *Banksia oblongifolia, Glochidion ferdinandi* and *Eucalyptus robusta*. In recent years there appears to be an increased spread of drier species such as *Corymbia gummifera* as a result of draining and decreased rainfall. We infer this community occupied about 1.2 hectares of the landing place reserve (Fig. 8).

6. Scrub on Sandstone

Scrub on sandstone currently occurs mostly on the southern side of Cape Solander Drive, with a small remnant occurring to the north of the road. Again, there is a dearth of early photographs or historical documents to help us develop a picture of this pre-1770 community, rather it is the remnants that provide us with the clues. South of Cape Solander Drive, and along the foreshores near Inscription Point (Fig. 2), the remnants are in good condition. The canopy is dominated by *Angophora costata* and *Eucalyptus haemastoma*, whilst the shrub layer includes *Acacia ulicifolia, Kunzea ambigua* and *Melaleuca nodosa*. Other species include *Allocasuarina distyla, Leucopogon ericoides* and *Pteridium esculentum*. We infer this community occupied about 7.5 hectares of the landing place reserve (Fig. 8).

7. Foreshore scrub on sand

Patches of foreshore scrub are likely to have occurred on the sand ridge behind the small beaches along Botany Bay, probably interspersed with more open grassy areas. Species probably depended on local conditions and included *Leptospermum laevigatum, Acacia longifolia* subsp. *sophorae, Banksia integrifolia, Casuarina glauca* with understorey such as *Isolepis nodosa, Stephania japonica* and *Commelina cyanea*.

8. Foreshore scrub on sandstone

Sandstone foreshores such as on Inscription Point have similar species to the sandstone scrubmore sandstone with some additional salt tolerant species such as *Banksia integrifolia, Westringia fruticosa* and *Melaleuca armillaris*.

Rehabilitation of remnant native vegetation

In 1965 Johnson & Briggs (LAS Johnson was later Director of the Royal Botanic Gardens Sydney) wrote *The Kurnell Peninsula and surrounding areas were the scene of the first botanical collecting in eastern Australia and carried an interesting and varied vegetation and flora. The Captain Cook's Landing Place Park includes only a few of the communities of the area, but these are all well worthy of preservation (which means no interference, no "improvement", no planting, of natives or otherwise, outside those areas already 'developed' for recreational purposes).*

Since the National Parks and Wildlife Service assumed control of the site in 1967, Johnson & Briggs's advice has largely been followed; however now it is time to give consideration to managing and restoring the vegetation in those areas that have been *developed for recreational purposes*. There are many good reasons for this; honoring the work of Banks and Solander; saving remnants of what are now endangered communities; acknowledging the plant resources that were available to Aboriginal people; and providing a vegetation "backdrop" to the interpretation of the history of the site.

Revegetation Strategies

Revegetation of the site is a complex task. There are a number of considerations in developing a revegetation strategy, foremost is working out which areas to focus revegetation on. Partly this depends on which areas have capacity for effective regeneration. The remnant vegetation communities are of variable condition and extent, some such as the coastal scrub of the southern knoll display reasonable species diversity and have good potential for effective rehabilitation, others such as the swamp forest have been substantially disturbed and almost need to be rebuilt. Introduced plantings add a further dimension to the strategy, not only due to their impact on native communities but because some have developed significant cultural value as evidence of the more recent history of the park (Design 5, 2006). The strategy must consider the presence of remnant plant communities recognized as endangered under NSW legislation. A further consideration in determining the focus for revegetation activities is the potential for the landscape to provide a backdrop to the interpretation of the site, helping visitors to immerse themselves in understanding the events of 1770.

It will be necessary to employ adaptive management to restore the vegetation communities of the site. The coastal scrub on the southern sandy knoll may be a good place to begin. It is a recognized endangered community (Kurnell Dune Forest) and one of the communities most disturbed by past management activities, it includes species collected by

Banks and Solander and, given its location behind the landing site, it has the potential to provide a backdrop to the story of encounter between Cook's crew and the local Gweagal people. The community is generally in poor condition but contains enough native vegetation to support regeneration. The dominant problems here are exotic species, both trees and ground species, and the relative paucity of natural native species regeneration.

It is suggested that restoration be commenced in this area, not only to restore this area, but with a view to contributing to a model for restoration that could be extended to other areas of the site. Suggested treatment for the southern knoll includes:

- Removal of *Eucalyptus microcorys* Tallowwood trees (and other introduced canopy species) – reducing the artificial canopy and creating more open conditions that may favour natives
- Spot poisoning of *Asparagus aethiopicus*, or hand removal of plants.
- Trial burning of strips say 50m wide to see whether native regrowth is improved
- Planting of *Banksia integrifolia* and *Monotoca elliptica* in local clusters
- Planting of native groundlayer species that are likely to spread readily, particularly vegetatively eg. *Pteridium esculentum, Microlaena stipoides, Themeda australis, Calochlaena dubia, Imperata cylindrica, Dodonaea triquetra.*
- Use of woodchip mulch to control exotic grasses and provide additional fire fuel.

Conclusion

At Botany Bay in 1770 all those on the *Endeavour*, including Cook, Banks and Solander, encountered a landscape that had remained largely unchanged for thousands of years. They were fascinated by flora and fauna and the diversity of species they encountered and their resulting specimen collections continue to be of botanical interest. By analysing various plant lists and historical records we have been able to prepare a definitive list of the specimens they collected, together with a picture of the landscape and vegetation communities they encountered when they landed at Botany Bay.

Following settlement of the area by Europeans in the early 1800s, landscape disturbance and the extensive planting of non-local, often robust and long-lived species, throughout the area of the landing site has guaranteed the persistence of a hybrid landscape for many decades. However, remnants of the pre-European species and communities remain, and these provide the opportunity to restore some of the landscapes that were the backdrop to the encounters between Cook's crew and the local Aboriginal people in 1770.

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Appendix 1. Distribution of remnant native plant species (recorded in 2004–2006) among inferred plant communities of the Cook's Landing site, Kurnell.

FS=Foreshore Scrub on sandstone; CsSwl= Coastal Sand Scrub-woodland; DuneF=Dune Forest; LitRF= Littoral rainforest; SwampF=Swamp Forest; SedgeSw= Sedgeswamp; SsScrub= Sandstone Scrub

Species	Coll. Bot. Bay 1770	Present At Kurnell	FS	CsSwl	DuneF	LitRF	SwampF	SedgeSw	SsScrub
Acaca implexa (Fabaceae)		2005		CsSwl					
Acacia binervia (Fabaceae)		2004			DuneF				
Acacia floribunda (Fabaceae)		2004		CsSwl					
Acacia longifolia (Fabaceae)	1770	2004		CsSwl	DuneF				SsScrub
Acacia suaveolens (Fabaceae)	1770	2004			DuneF				SsScrub
Acacia terminalis subsp. *angustifolia* (Fabaceae)		2004			DuneF				
Acacia ulicifolia (Fabaceae)	1770	2004		CsSwl	DuneF				SsScrub
Actinotus helianthi (Apiaceae)	1770	2004			DuneF				SsScrub
Allocasuarina distyla (Casuarinaceae)	1770	2004							SsScrub
Allocasuarina littoralis (Casuarinaceae)	1770	1977			DuneF				
Angophora costata (Myrtaceae)	1770	2004		CsSwl	DuneF				SsScrub
Aotus ericoides (Fabaceae)	1770	2004			DuneF				
Astroloma pinifolium (Ericaceae)	1770	2004			DuneF				
Baloskion tetraphyllum subsp. *meiostachyus* (Restionaceae)	1770	2004						SedgeSw	
Banksia integrifolia (Proteaceae)	1770	2004	FS	CsSwl	DuneF				
Banksia oblongifolia (Proteaceae)		2004						SedgeSw	
Banksia serrata (Proteaceae)	1770	2004		CsSwl	DuneF				
Billardiera scandens (Pittosporaceae)		2004			DuneF				
Blechnum camfieldii (Blechnaceae)	1770	2004						SedgeSw	
Blechnum indicum (Blechnaceae)	1770	2004						SedgeSw	
Bossiaea heterophylla (Fabaceae)	1770	2004			DuneF				
Bossiaea scolopendria (Fabaceae)		2004			DuneF				
Brachyloma daphnoides (Ericaceae)		2004			DuneF				
Breynia oblongifolia (Euphorbiaceae)	1770	2004	FS	CsSwl	DuneF		SwampF		SsScrub
Callistemon citrinus (Myrtaceae)	1770	2004						SedgeSw	
Calochlaena dubia (Dicksoniaceae)		2004				LitRF	SwampF	SedgeSw	
Casuarina glauca (Casuarinaceae)		2004	FS	CsSwl			SwampF		
Centella asiatica (Apiaceae)		2004		CsSwl					
Ceratopetalum gummiferum (Cunoniaceae)		2004			DuneF				
Cissus hypoglauca (Vitaceae)		2005					SwampF		
Clematis aristata (Ranunculaceae)		2004		CsSwl					
Clerodendrum tomentosum (Verbenaceae)		2004		CsSwl					
Commelina cyanea (Commelinaceae)	1770	2004		CsSwl		LitRF	SwampF		
Corymbia gummifera (Myrtaceae)	1770	2004			DuneF			SedgeSw	
Cryptocarya ?microneura (Lauraceae)		2004						SedgeSw	
Cupaniopsis anacardioides (Sapindaceae)		2004		CsSwl		LitRF	SwampF		
Cymbopogon refractus (Poaceae)		2004		CsSwl					
Daviesia mimosoides (Fabaceae)		2004			DuneF				
Desmodium varians (Fabaceae)		2004		CsSwl					
Dianella caerulea (Dianellaceae)		2004		CsSwl			SwampF		

Species	Coll. Bot. Bay 1770	Present At Kurnell	FS	CsSwl	DuneF	LitRF	SwampF	SedgeSw	SsSerub
Dianella longifolia (Dianellaeeae)		2004			DuneF		SwampF		SsSerub
Dichondra repens (Convolvulaeeae)		2004		CsSwl					
Dillwynia retorta (Fabaeeae)		2004							SsSerub
Dodonaea triquetra (Sapindaeeae)		2004			DuneF				SsSerub
Echinopogon ovatus (Poaeeae)		2004			DuneF				
Elaeocarpus reticulatus (Elaeocarpaeeae)		2004		CsSwl	DuneF		SwampF		SsSerub
Epacris longiflora (Erieaeeae)	1770	2004							SsSerub
Eragrostis brownii (Poaeeae)		2004			DuneF				SsSerub
Eucalyptus botryoides (Myrtaeeae)		2004		CsSwl	DuneF				
Eucalyptus haemastoma (Myrtaeeae)		2004			DuneF				
Eucalyptus piperita (Myrtaeeae)		2004			DuneF				
Eucalyptus robusta (Myrtaeeae)		2004		CsSwl			SwampF		
Eustrephus latifolius (Philesiaeeae)	1770	2004		CsSwl	DuneF		SwampF		
Ficus rubigin osa (Moraeeae)		2004		CsSwl			SwampF		
Gahnia sieberiana (Cyperaeeae)		2004					SwampF	SedgeSw	
Geitonoplesium cymosum (Phylesiaeeae)		2004		CsSwl					
Geranium homeanum (Geraniaeeae)	1770	2004				LitRF			
Gleichenia dicarpa (Gleicheniaeeae)		2004						SedgeSw	
Glochidion ferdinandi (Euphorbiaeeae)		2004	FS		DuneF		SwampF	SedgeSw	
Glycine ?clandestina (Fabaeeae)		2004			DuneF				
Glycine tabacina (Fabaeeae)	?1770	2004		CsSwl					
Gompholobium grandiflorum (Fabaeeae)		2004			DuneF				
Gonocarpus teucrioides (Haloragaeeae)		2004			DuneF				
Goodenia ?paniculata/stelligera (Goodeniaeeae)		2004							SsSerub
Grevillea mucronulata (Proteaeeae)	1770	2004			DuneF				
Haemodorum planifolium (Haemadoraeeae)		2005			DuneF				
Hakea sericea (Proteaeeae)		2004						SedgeSw	
Hardenbergia violacea (Fabaeeae)	?1770	2004		CsSwl	DuneF				
Hibbertia empetrifolia (Dilleniaeeae)		2004			DuneF				
Hibbertia scandens (Dilleniaeeae)	1770	2004			DuneF		SwampF	SedgeSw	
Hybanthus monopetalus (filiformis) (Violaeeae)	1770	2004		CsSwl					
Hydrocotyle peduncularis (Apiaeeae)		2004		CsSwl		LitRF	SwampF		
Hypolepis muelleri (Dennstaedtiaeeae)		2004				LitRF			
Imperata cylindrica (Poaeeae)		2004		CsSwl	DuneF		SwampF		
Indigofera australis (Fabaeeae)		2004		CsSwl					
Isolepis nodosa (Cyperaceae)		2004	FS	CsSwl					
Kennedia rubicunda (Fabaeeae)	1770	2004		CsSwl			SwampF		
Kunzea ambigua (Myrtaeeae)		2004							SsSerub
Lepidosperma laterale (Cyperaeeae)		2004		CsSwl	DuneF				
Lepidosperma sp. (tall) (Cyperaeeae)		2004						SedgeSw	
Leptospermum laevigatum (Myrtaeeae)	1770	2004	FS	CsSwl					
Leptospermum trinervium (Myrtaeeae)	1770	2004			DuneF				
Lepyrodia scariosa (Restionaeeae)		2004							SsSerub
Leucopogon ericoides (Erieaeeae)	1770	2004			DuneF				SsSerub
Livistona australis (Areeaeeae)	?1770	2004				LitRF	SwampF	SedgeSw	
Lomandra longifolia (Lomandraeeae)	1770	2004	FS	CsSwl	DuneF				
Macrozamia communis (Zamiaeeae)	1770	2004		CsSwl	DuneF				

Species	Coll. Bot. Bay 1770	Present At Kurnell	FS	CsSwl	DuneF	LitRF	SwampF	SedgeSw	SsScrub
Marsdenia rostrata (Asclepiadaceae)		2004					SwampF		
Melaleuca armillaris (Myrtaceae)	1770	1981	FS						
Melaleuca nodosa (Myrtaceae)	1770	2004							SsScrub
Melaleuca quinquenervia (Myrtaceae)		2004				LitRF	SwampF		
Microlaena stipoides (Poaceae)		2004		CsSwl			SwampF		
Monotoca elliptica (Ericaceae)		2004		CsSwl	DuneF				SsScrub
Notelaea longifolia (Oleaceae)		2004		CsSwl			SwampF		
Omolanthus populifolius (Euphorbiaceae)		2004		CsSwl		LitRF	SwampF		
Oplismenus aemulus (Poaceae)		2004					SwampF		
Oplismenus imbecillis (Poaceae)		2004		CsSwl					
Oxalis sp. (Oxalidaceae)		2004			DuneF				
Oxylobium cordifolium (Fabaceae)	1770	2004							SsScrub
Persicaria decipiens (Polygonaceae)		2004					SwampF		
Persoonia laevis (Proteaceae)		2004			DuneF				
Persoonia lanceolata (Proteaceae)	1770	2004			DuneF				SsScrub
Phragmites australis (Poaceae)		2004					SwampF		
Pimelea linifolia (Thymelaeaceae)	1770	2004			DuneF				SsScrub
Pittosporum revolutum (Pittosporaceae)		2004		CsSwl	DuneF		SwampF		
Pittosporum undulatum (Pittosporaceae)		2004		CsSwl			SwampF		
Platysace ericoides (Apiaceae)	1770	2005			DuneF				
Platysace lanceolata (Apiaceae)	1770	2004							SsScrub
Plectranthus parviflorus (Lamiaceae)	1770	2004		CsSwl					
Poa sp. (Poaceae)		2004						SedgeSw	
Pomax umbellata (Apiaceae)	1770	2004		CsSwl	DuneF				SsScrub
Portulacca oleracea (Portulacaceae)		2004	FS	CsSwl					
Pratia purpurascens (Lobeliaceae)	1770	2004				LitRF			
Pteridium esculentum (Dennstaedtiaceae)	1770	2004		CsSwl	DuneF	LitRF	SwampF	SedgeSw	SsScrub
Pterostylis sp. (Orchidaceae)		2004		CsSwl					
Ricinocarpos pinifolius (Euphorbiaceae)	1770	2004			DuneF				
Sarcopetalum harveyanum (Menispermaceae)		2004		CsSwl	DuneF				
Senecio ?hispidulus (Asteraceae)		2004					SwampF		
Smilax glyciphylla (Smilacaceae)		2004		CsSwl	DuneF		SwampF		
Stephania japonica (Menispermaceae)	1770	2005	FS						
Syzygium paniculatum (Myrtaceae)		2006				LitRF			
Themeda australis (Poaceae)		2004		CsSwl	DuneF				
Typha orientalis (Typhaceae)		2004					SwampF		
Viola banksii (Violaceae)	1770	2004				LitRF	SwampF		
Westringia fruticosa (Lamiaceae)	1770	1981	FS						
Xanthorrhoea arborea (Xanthorrhoeaceae)		2004		CsSwl	DuneF				
Xylomelum pyriforme (Proteaceae)	1770	2004		CsSwl	DuneF				

Plant species first recognised as naturalised for New South Wales in 2002 and 2003, with additional comments on species recognised as naturalised in 2000–2001

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Abstract: Information is provided on the taxonomy and distribution of 71 taxa of naturalised or naturalising plants newly recorded for the state of New South Wales during the period 1 January 2002 to 31 December 2003. Of these taxa, 32 are new records for Australia (prefaced with a †). These species are: *Abutilon pictum*, *Acanthus mollis*, †*Aesculus indica* (naturalising), *Agapanthus praecox* subsp. *orientalis*, *Ajuga reptans*, †*Anigozanthos flavidus*, *Aquilegia vulgaris*, *Arbutus unedo*, †*Athertonia diversifolia* (naturalising), †*Bergenia* x *schmidtii* (naturalising), *Bromus catharticus* subsp. *stamineus*, *Bryophyllum daigremontianum*, *Bryophyllum fedtschenkoi*, *Calyptocarpus vialis*, †*Ceiba speciosa* (naturalising), *Cereus uruguayanus*, †*Cestrum* x *cultum*, †*Chamaecyparis lawsoniana*, *Cistus salviifolius*, †*Clematis montana*, †*Coprosma* x *cunninghamii*, *Coprosma robusta*, *Cornus capitata*, *Cotoneaster simonsii*, *Cotoneaster* x *watereri* group, *Crinum moorei*, *Cupressus lusitanica*, †*Cylindropuntia fulgida* var. *mamillata* forma *monstrosa*, †*Cylindropuntia prolifera*, *Cylindropuntia tunicata*, *Desmanthus virgatus*, *Drosanthemum candens*, †*Elaeagnus umbellata* (naturalising), †*Eragrostis trichophora*, †*Eupatorium lindleyanum*, †*Gibasis pellucida*, *Glechoma hederacea*, †*Hesperis matronalis*, *Hieracium aurantiacum* subsp. *carpathicola*, †*Inga edulis* (naturalising), †*Juniperus conferta* (naturalising), †*Justicia caudata*, *Lamium galeobdolon*, *Lathyrus tingitanus*, †*Lysimachia fortunei*, †*Maackia amurensis*, †*Monstera deliciosa*, †*Murdannia keisak*, *Odontonema tubaeforme*, *Oxalis vallicola*, *Phoenix canariensis*, †*Physostegia virginiana*, *Pinus patula*, *Pittosporum eugenioides*, †*Pittosporum ralphii*, *Pittosporum tenuifolium*, *Plectranthus ecklonii*, †*Potentilla vesca*, †*Prunus campanulata*, †*Rhododendron ponticum*, *Rosa luciae*, *Rubus rugosus*, *Ruellia squarrosa*, †*Senna multijuga*, *Stapelia gigantea*, *Stephanophysum longifolium*, *Strobilanthes anisophylla*, †*Tabebuia chrysotricha*, †*Tabebuia impetiginosa*, †*Tradescantia pallida* and *Ulmus* x *hollandica*.

Additional notes and name changes are recorded for plants first recognised as naturalised for New South Wales over the period 2000–2001. The identification of several naturalised taxa occurring in New South Wales has been corrected. Plants formerly identified as *Pinus nigra* var. *corsicana* are now considered to be *Pinus halepensis*; *Cylindropuntia arbuscula* is *Cylindropuntia kleiniae*, *Cylindropuntia tunicata* is *Cylindropuntia rosea*, *Abrus precatorius* subsp. *precatorius* is now *Abrus precatorius* subsp. *africanus* and *Cotoneaster ?horizontalis* is *Cotoneaster microphyllus*. Further field studies have revealed that *Cylindropuntia leptocaulis*, *Cylindropuntia spinosior*, *Hypericum konytchense* and *Chamaesyce ophthalmica* are more widespread than previously thought.

Cunninghamia **10(1): 139–166**

Introduction

This paper is part of a series covering species recognised as naturalised or naturalising by the National Herbarium of New South Wales (standard code for this herbarium, NSW, is used throughout this paper). An earlier paper covered the period 2000–2001 (Hosking et al. 2003). This paper draws attention to a number of new naturalisations recorded for the state of New South Wales (N.S.W.) and the Australian Capital Territory (A.C.T.) over the period 2002–2003, and follows the format of Hosking et al. (2003). Only taxa considered to be spreading from initial plantings or other naturalisations (e.g. from discarded garden refuse) are covered. 'Naturalised' in this paper refers to non-native taxa that have been reproducing (sexually or vegetatively) in the wild for at least one generation. 'Naturalising' covers taxa that are growing in the wild that have not yet reproduced, or are not spreading vegetatively.

Methods

All taxa treated are represented by vouchers lodged at NSW or the Australian National Herbarium, Canberra (CANB). A number of taxa listed were first collected prior to 2002 but are included here as these records were overlooked for *Flora of New South Wales* accounts and were subsequently noted during 2002 or 2003. Following recent collections a few old herbarium specimens stored at the end of genera and families in the NSW collection were able to be determined to species. There are also likely to be other records of recently naturalised species collected in the area during 2002 and 2003 that are housed at other Australian herbaria; we urge all collectors to lodge material collected from the Australian Capital Territory or New South Wales at either CANB or NSW.

The *Germplasm Resources Information Network database* (USDA) (URL http://www.ars-grin.gov/cgi-bin/npgs/html/taxgenform.pl) and the International Plant Name Index (http://www.us.ipni.org/index.html) were extensively consulted to determine currently accepted names, authorities and native range of taxa covered in this paper. The *PlantNET* website (NSW) (http://plantnet.rbgsyd.nsw.gov.au) was used to determine the current status of knowledge of introduced plants in N.S.W. The *NSW Collections* (NSW) and *Australian National Herbarium Specimen Information Records* (CANB) databases, together with the *Australia's Virtual Herbarium* website (http://www.chah.gov.au/avh/) were extensively used to determine the known records of introduced taxa.

Taxon names used are those currently adopted by NSW and can be viewed in the Flora Online module of *PlantNET* (http://plantnet.rbgsyd.nsw.gov.au). Herbarium codes follow Holmgren et al. (1990).

Information on means of dispersal of various taxa treated in this paper is given under 'Notes' for each taxon where this is known. Where the dispersal mechanism is not listed, the taxon concerned is presumed to spread by seed. However, the actual means of dispersal is not known for a number of taxa treated.

Discussion

The definition of the term 'naturalised' as used in this paper is outlined above. However, given that there is a degree of disagreement as to how this term should be applied (see Richardson et al. 2000, Pyšek et al. 2004), we have provided additional information on numbers of plants present, area covered and reproductive status of all taxa treated in this paper to allow for these differences in interpretation.

There are many ways of detecting new plant naturalisations (Hosking et al. 2001). The records listed below are the result of (i) collections made by experts who have a reasonable knowledge of local floras, including local government weeds officers, environmental consultants, bush regenerators, professional botanists and staff from Landcare and Greening Australia, and (ii) specimens retained by herbaria who provide plant identifications for the general public.

More species (71 species) were first recorded as naturalised in N.S.W. during 2002 and 2003 compared with 40 for 2000 and 2001 (see Hosking et al. 2003), mainly due to increased effort to record naturalised plants in the Blue Mountains near Sydney, an area with a long history of ornamental horticulture. Records from Bellingen Hospital grounds, Bellingen, on the N.S.W. North Coast, cover species naturalising in an old arboretum (with management now limited primarily to path maintenance).

It is hoped that publication of new records of plant species naturalised in N.S.W. will prompt further collections of introduced species. In the long term, this approach will focus attention on potential problem species, and hopefully lead to their eradication before they have the opportunity to spread and become serious weeds.

Plant species first recognised as naturalised in New South Wales during 2002 and 2003

Taxa are listed alphabetically by family, genus and species under Conifers and allies, Monocotyledons and Dicotyledons. Vernacular names (where known), references to published descriptions (including illustrations and photographs), region of origin, distribution within N.S.W. according to botanical regions, habitat preferences, first known and additional herbarium records and miscellaneous notes (including relative abundance, invasiveness and whether naturalised in other states or overseas) are also provided. Authorities for species are those currently recognised at NSW.

Conifers and allies

CUPRESSACEAE

Chamaecyparis lawsoniana (A.Murray) Parl.

Lawson's Cypress, Port Orford Cedar

Description: Tree to 50 m high. See Wright (1984), Sykes in Webb et al. (1988), Michener in Morin (1993), Krüssmann (1985) and Bartel in Hickman (1993).

Region of Origin: Native of the USA (northern California, south western Oregon).

New South Wales Distribution / Habitats: Central Tablelands. Naturalised in disturbed shrubby *Eucalyptus piperita*, *E. sieberi* and *E. mannifera* woodland near planting of *Chamaecyparis lawsoniana*.

First Record: Wellington Road end of Burrawang Road, south of Wellington Road, Katoomba, *C.H. Barker 16 & J.R. Hosking*, 3 Dec 2003 (CANB, MEL, NE, NSW).

Notes: At the Katoomba site there were seven naturalised trees 1–6 m high, up to 40 m from an 18 m high parent planted tree. Two naturalised trees had cones. Spread appears to be by wind-dispersed seed. Seedlings have since been noted around other plantings in the Katoomba area. Many cultivars have been developed from *C. lawsoniana* (Krüssmann 1985). This species is not known to be naturalised in other Australian states but is naturalised in New Zealand and Europe (Sykes in Webb et al. 1988, Tutin in Tutin et al. 1964).

Cupressus lusitanica Mill.

Arizona Cypress, Mexican Cypress

Description: Tree to 20 m high. See Krüssmann (1985) and Dallimore (1936).

Region of Origin: Native of Mexico, El Salvador, Guatemala and Honduras.

New South Wales Distribution / Habitats: Central Tablelands. Naturalised near plantings of this species. Growing on the edge of *Eucalyptus piperita* woodland with a shrubby understorey dominated by *Hakea dactyloides* and *Acacia terminalis* on sandstone-derived yellow-brown sand at Blackheath; at Katoomba it was collected from *Eucalyptus sieberi*, *E. piperita* and *E. blaxlandii* open forest with an understorey of mostly native species and *Cotoneaster franchetii*.

First Record: Roadside, Mt Wilson, *K. Hill 3827*, 9 Feb 1991.

Additional Records: Area of native vegetation alongside Blackheath Golf Course below end of Jubilee Avenue, Blackheath, *J.R. Hosking 2247 & C.H. Barker*, 27 Nov 2002 (CANB, MEL, NE, NSW); Eastern side of Katoomba Cemetery, *J.R. Hosking 2440 & C.H. Barker*, 7 Feb 2004 (CANB, MEL, NE, NSW).

Notes: At the Blackheath site there were many hundreds of naturalised young plants ranging in age from juveniles to cone-bearing trees to 5 m high, growing alongside a line of planted trees to 20 m high. At Katoomba there were about 20 plants up to 3 m high, but none of the naturalising plants were cone-bearing. Wildings have also been observed at other locations in the upper Blue Mountains; all collections have been from near cultivated trees. Spread appears to be by wind-dispersed seed. This species is doubtfully naturalised at Mt Glorious, west of Brisbane in Queensland (*Phillips 159* – BRI). There are no herbarium records of naturalised *C. lusitanica* elsewhere in Australia. *Cupressus lusitanica* is naturalised in Europe and on plantation margins in New Zealand (Franco in Tutin et al. 1964, Webb et al. 1995). It is considered invasive in Malawi (Cronk & Fuller 1995).

Juniperus conferta Parl.

Shore Juniper

Description: Groundcover to 70 cm high. See Makino (1964), Ohwi (1965) and Krüssmann (1985).

Region of Origin: Native to Japan (western Hokkaido, coastal Honshu, Kyushu) and the Russian Federation (Sakhalin).

New South Wales Distribution / Habitats: Central Tablelands. Growing in shrubby woodland alongside and amongst *Leptospermum polygalifolium*, *Hakea dactyloides*, *Eucalyptus sieberi* and *E. piperita*, on sandstone-derived yellow sand mixed with humus to form a brown humic loam.

First Record: Roadside native vegetation between Katoomba Golf Course and Narrow Neck Road, over road from end of Essendene Road, Katoomba, *J.R. Hosking 2241 & C.H. Barker*, 25 Nov 2002 (CANB, MEL, NE, NSW).

Notes: There appears to be only one plant (with male cones) at the collection site occupying a circular area about 2 m diameter. This plant appears to have originated from dumped garden waste. There are scattered *Juniperus* plants elsewhere in the Blue Mountains but it is not certain if they are the same species. *Juniperus conferta* is not known to be naturalised elsewhere in Australia.

PINACEAE

Pinus patula Schiede ex Schltdl. & Cham.

Patula Pine, Mexican Weeping Pine

Description: Pine tree to 45 m high. See Sykes in Webb et al. (1988) and Henderson (2001).

Region of Origin: Native from Mexico to Nicaragua.

New South Wales Distribution / Habitats: Central Coast, Northern Tablelands and Central Tablelands. Naturalised alongside plantings.

First Record: South of lower dam, Ponderosa Picnic Area, Hanging Rock State Forest, *J.R. Hosking 2220*, 15 Jun 2002 (CANB, MEL, NE, NSW).

Additional Records: opposite 10 Angel Street, Wentworth Falls, *C.H. Barker 59*, 8 May 2004 (CANB, MEL, NE, NSW); Bell's Line of Road, Bilpin, 2.2 km east of Powell's Road, *C.H. Barker 61*, 11 May 2004 (CANB, MEL, NE, NSW).

Notes: There are over 100 trees of all ages naturalised at the *Hosking 2220* collection site where some naturalised plants were found over 100 m from cone-bearing plants. Recent specimens from the Blue Mountains are from smaller populations containing cone-bearing naturalised plants. This pine is spread by wind-dispersed seed, with minor spread associated with Yellow-tailed Black Cockatoos moving seed-bearing cones. Young trees with drooping needles are easily distinguished from most other naturalised pines in Australia. *Pinus patula* is one of the five most invasive *Pinus* species according to Rejmánek and Richardson (1996). It is naturalised in Victoria (Ross & Walsh 2003) and Queensland (BRI specimens), and is considered to be a problem in New Zealand, South Africa, Malawi and Hawaii (Sykes in Webb et al. 1988, Henderson 2001, Cronk & Fuller 1995).

Monocotyledons

ALLIACEAE

Agapanthus praecox Willd. subsp. ***orientalis*** (F.M.Leight.) F.M.Leight.

Agapanthus

Description: Herb with inflorescence spikes to 1.5 m high. See Conran in Walsh & Entwisle (1994), Healy & Edgar (1980) and Sims (1800, as *Agapanthus umbellatus* Ait.).

Region of Origin: Native of South Africa (Cape Province, Natal).

New South Wales Distribution / Habitats: Central Tablelands. Growing on sandstone-derived sandy soils in forests, woodlands, ditches and cliff ledges in areas near plantings or where garden refuse has been dumped. This species is also naturalised in the lower Blue Mountains and Sydney.

First Record: Roadside native vegetation between Katoomba Golf Course and Narrow Neck Road, over road from end of Essendene Road, Katoomba, *J.R. Hosking 2209*, 23 Apr 2002 (CANB, MEL, NE, NSW).

Notes: There are many hundreds of plants at the collection site and the species is also abundant on cliff face ledges below Echo Point Lookout, the main viewing point for the Three Sisters at Katoomba, where seed appears to have been washed over the cliff edge from plantings. *Agapanthus praecox* subsp. *orientalis* is naturalised at other locations in the Blue Mountains as a result of seed dispersal and dumping of rhizomes in garden waste or movement of rhizomes in water. The species is naturalised in Victoria, Tasmania and Western Australia (Conran in Walsh & Entwisle 1994, Blood 2001, Hussey et al. 1997) and in New Zealand, Britain (Isles of Scilly), Madeira and the Canary Islands (Healy & Edgar 1980, Webb in Tutin et al. 1980, Hansen & Sunding 1993).

AMARYLLIDACEAE

Crinum moorei Hook.f.

Description: Herb to 1.4 m high. See Wood (1912), Gibson (1975) and Hooker (1874).

Region of Origin: Native of South Africa (Cape Province, Natal).

New South Wales Distribution / Habitats: Central Coast. Only known to be naturalised at Valley Heights (lower Blue Mountains) where it is growing with *Eucalyptus punctata*, *Allocasuarina torulosa*, *Angophora costata*, *Ligustrum sinense*, *Syncarpia glomulifera* subsp. *glomulifera*, *Corymbia gummifera*, *Lomandra longifolia* and native grasses and sedges. In this area plants were growing on sandstone.

First Record: Area of mostly native vegetation in break between two sections of Taylor Road, Valley Heights, *J.R. Hosking 2286 & C.H. Barker*, 26 Mar 2003 (CANB, MEL, NE, NSW).

Notes: At Valley Heights there were 12 naturalised plants below a garden where there were many cultivated plants. Means of spread is unknown but naturalised plants are downslope from existing plantings. This species is listed as possibly naturalised in Western Australia (Hussey et al. 1997).

ARACEAE

Monstera deliciosa Liebm.

Fruit-salad Plant, Monstera

Description: Woody vine or herb mostly to 1.5 m high. See Mason & Mason (1987).

Region of Origin: Native of Costa Rica, Guatemala, Mexico (Chiapas, Oaxaca, Veracruz) and Panama.

New South Wales Distribution / Habitats: North Coast, Central Coast. Grows in many coastal areas where garden refuse had been dumped.

First Record: Area of mostly native vegetation in break between two sections of Taylor Road, Valley Heights, *J.R. Hosking 2287 & C.H. Barker*, 26 Mar 2003 (CANB, MEL, NE, NSW).

Notes: The specimen was collected from a single plant occupying an area 5 m x 5 m. Naturalised plants are scattered over the lower to mid Blue Mountains City Council area. Plants have large leaves and fruit. They are readily recognised and this may explain why this species has not been collected previously. The authors know of naturalised plants in a number of coastal locations throughout N.S.W. but there are no herbarium specimens from these locations. In most cases plants appear to occur singly and have probably arisen from dumped garden waste. This also seems to be the case in Queensland (Batianoff pers. comm., Nov 2005) where the species is recorded as doubtfully naturalised (*Batianoff 0308267*, *Phillips 1123* – BRI). The species appears to have naturalised in Victoria where plants were recorded growing in a drain in suburban Melbourne (*Lepschi 6092 and Connors* – CANB, MEL). The species has naturalised in Florida (Wunderlin & Hansen 2004).

ARECACEAE

Phoenix canariensis hort. ex Chabaud

Canary Island Palm

Description: Palm to 15 (rarely to 20) m high. See Conn & Walsh in Walsh & Entwisle (1994), Healy & Edgar (1980), Barrow (1998) and Riffle & Craft (2003).

Region of Origin: Native of Canary Islands.

New South Wales Distribution / Habitats: Central Coast, North Western Slopes, Central Western Slopes and South Western Slopes. Growing in a damp gully in Oxley Park, Tamworth, with mostly exotic species such as *Ligustrum lucidum*, *Schinus molle* var. *areira*, *Pyracantha crenulata* and *Photinia serratifolia*. Growing in a disturbed roadside

remnant of shrubby *Eucalyptus microcarpa* / *E. sideroxylon* subsp. *sideroxylon* woodland near Koorawatha, and with *Eucalyptus camaldulensis* and *Schinus molle* var. *areira* along a creek at Bimbi. Naturalised amongst *Eucalyptus camaldulensis* forest alongside the Murrumbidgee River at Wagga Wagga and Narrandera.

First Record: Oxley Park, Tamworth, *J.R. Hosking s.n.*, 26 Sep 1987 (NE, NSW).

Additional Records: 1.5 km W of Godfreys Creek Road on Sutherland Road (= Koorawatha Road), c. 11.5 km E of Koorawatha, *B.J. Lepschi 4863, R.C. Godfree & D.J. Mallinson*, 16 Oct 2002 (CANB, NSW), Burrangong Creek, c. 300 m E of bridge on Grenfell – Quandialla road, Bimbi settlement, *B.J. Lepschi 5538 & R.C. Godfree*, 28 Mar 2006 (CANB, MO, NSW).

Notes: *Phoenix canariensis* is probably widely naturalised in disturbed areas close to where it has been planted, but is readily recognised and rarely submitted as herbarium specimens for identification. Large fronds of this species may also discourage collectors. It is abundant alongside the Murrumbidgee River at Wagga Wagga and Narrandera although no collections have been made from the area. It has also been observed (but not collected) along gullies in the lower Blue Mountains, through much of western Sydney, and on roadsides on the South West and Central West Slopes. Spread appears to be via movement of fruit, possibly by bats. Naturalised in Victoria and South Australia (Conn & Walsh in Walsh & Entwisle 1994, Smyth in Barker et al. 2005) and in New Zealand and the USA (Healy & Edgar 1980, McClintock in Hickman 1993).

COMMELINACEAE

Gibasis pellucida (M.Martens & Galeotti) D.R.Hunt

Tahitian Bridal Veil

Description: Trailing herb to 10 cm high, rooting at nodes. See Hunt (1986) and Faden in Morin (2000).

Region of Origin: Native of Mexico.

New South Wales Distribution / Habitats: Central Coast. Known from sclerophyll forest in higher rainfall areas where it is spreading from plantings and dumped garden refuse.

First Record: Albatross Avenue Road Reserve, north of Singles Ridge Road, Winmalee, *C.H. Barker 30 & J.R. Hosking*, 5 Dec 2003 (CANB, MEL, NE, NSW).

Notes: Probably spreads locally via stems that root at nodes and over greater distance via movement of vegetative material and possibly seed. Known from the collection site in Winmalee and also seen spreading into sclerophyll forest behind houses at Yellow Rock. From the literature this species could potentially establish along watercourses in rainforest areas. Not recorded as naturalised elsewhere in Australia. This species is recorded as weedy in citrus groves and waste places in Florida (Faden in Morin 2000).

Murdannia keisak (Hassk.) Hand.-Mazz.

Marsh Dewflower

Description: Prostrate herb with flowering parts ascending to 25 cm high, rooting at nodes. See Kuo-Shih in Li et al. (1978b) and Faden in Morin (2000) under *M. keisak* and Makino (1964) and Ohwi (1965) under the name *Aneilema keisak* Hassk.

Region of Origin: Native of Japan, Korea, China, Vietnam, Laos, Cambodia and Nepal.

New South Wales Distribution / Habitats: Central Coast. Recorded from Lane Cove where plants grow at the edge of wet sclerophyll forest near gardens amongst other exotic plants.

First Record: 'The Run' at 'Susan Park', Mangrove Creek, *D.F. Blaxell 1284*, 6 Mar 1974 (NSW)

Additional Records: The Comenarra Parkway, near Jordan Road, Turramurra, *V. Klaphake 83*, 8 Mar 1987 (BRI, CANB, NSW); Near Innes Road entrance, Bushland Park, Lane Cove, *V. Klaphake 945*, 15 Dec 1993 (K, NSW).

Notes: This species is locally common in a number of parks in the Lane Cove municipality according to *Klaphake 945*. Probably spreads locally via spreading stems that root at nodes and over greater distance via movement of vegetative material and possibly seed. Not recorded as naturalised elsewhere in Australia. In Japan the species is common in wet places (Ohwi 1965). This species is still expanding its range in the USA since its introduction early in the 1900s (Faden in Morin 2000).

Tradescantia pallida (Rose) D.R.Hunt

Purple Queen, Purple Heart

Description: Trailing herb to 50 cm high, rooting at nodes. See Hunt (1975) and Faden in Morin (2000) under *T. pallida* and Graf (1968) under *Setcreasea pallida* Rose.

Region of Origin: Native of Mexico (Tamaulipas, Veracruz, Yucatan).

New South Wales Distribution / Habitats: North Western Slopes, Central Coast. Gullies in sclerophyll forest.

First Record: Oxley Park, Tamworth, *J.R. Hosking s.n.*, 13 Nov 1985 (NE, NSW).

Additional Records: below road to lookout, Oxley Park, Tamworth, *J.R. Hosking 727*, 31 Mar 1993 (CANB, MEL, NE, NSW); drainage reserve above junction of Dawes Place and Hume Road, Lapstone, *J.R. Hosking 2330 & C.H. Barker*, 21 Aug 2003 (CANB, MEL, NE, NSW).

Notes: This species appears to spread via stems that root at nodes. At Tamworth there is only one small clump of plants at the end of a drainage pipe below a road but this clump does not seem to have changed much in size since the initial collection in 1985, possibly because of restricted water

availability. At Lapstone, plants are spreading downslope in a disturbed gully, possibly originating from a garden above. Also naturalised in a disturbed riparian area at Greystanes in western Sydney. This species has not been recorded as naturalised elsewhere in Australia, but has been recorded on landfill and old home sites in Florida and Louisiana (Faden in Morin 2000).

HAEMORODORACEAE

Anigozanthos flavidus DC.

Yellow Kangaroo-paw

Description: Herb with scape to 3 m high. See Hopper in George (1987).

Region of Origin: Native of south western Western Australia.

New South Wales Distribution / Habitats: South Coast. Grows on sand in coastal woodland of *Banksia serrata*, *Corymbia gummifera* and *Syncarpia glomulifera*.

First Record: Near Lake McKenzie, Booderee Botanic Gardens, c. 3 km SW of Jervis Bay Settlement, *B.J. Lepschi 5047 & D.N. Brown*, 20 Nov 2003 (CANB, K, MO, NSW).

Notes: This species is a problem weed in and around Booderee Botanic Gardens, with many thousands of plants within the Garden grounds and adjacent Booderee National Park. The source of the introduction was via cultivated plants in the Botanic Garden, over a period of years since the 1960s. Intentional cultivation of this species at Booderee Botanic Garden ceased in the early 1990s when plantings were removed. It is spread via seed and rhizomes (through slashing and grounds maintenance). A control program for this species has been in place since 1997 with limited success. Not known to be naturalised elsewhere.

POACEAE

Bromus catharticus **Vahl subsp.** ***stamineus*** (E.Desv.) Massa

[syn. *Bromus catharticus* var. *elata* (E.Desv.) Planchuelo, *Bromus cebadilla* Steud., *Bromus fonkii* Phil., *Bromus lithobious* Trin., *Bromus stamineus* E.Desv.]

Chilean Brome

Description: Grass to 90 cm high. See Morris in Curtis & Morris (1994), Walsh in Walsh & Entwisle (1994), Sharp & Simon (2002), Massa et al. (2004) and Planchuelo (2006).

Region of Origin: Native of South America (Argentina, Chile).

New South Wales Distribution / Habitats: Southern Tablelands, Central Tablelands. Common in disturbed areas in the Blue Mountains.

First Record: Leura township, *E.J. McBarron 20633*, 17 Jan 1973 (NSW).

Additional Record: South side of Gates Avenue at bottom of hill, Katoomba, *C.H. Barker 21 & J.R. Hosking*, 3 Dec 2003 (CANB, MEL, NE, NSW).

Notes: We have followed Massa et al. (2004) in treating *B. catharticus* as a taxon comprising two subspecies *B. catharticus* subsp. *catharticus* and *B. catharticus* subsp. *stamineus*. This is not necessarily the approach that will be taken at NSW when taxonomic limits are further evaluated. Previous Australian treatments of this group (Sharp & Simon 2002, Wheeler et al. 2002) treat *Bromus catharticus* subsp. *stamineus* at specific rank, either as *B. lithobius* or as *B. cedabilla* (synonym *B. stamineus*). *Bromus catharticus* subsp. *stamineus* has previously been confused with *B. catharticus* subsp. *catharticus* but the former taxon has glabrous (rarely with a few scattered hairs) spikelets and awns to 3 mm long, whereas *B. catharticus* subsp. *stamineus* has hairy spikelets and awns 3–7 mm long. *Bromus catharticus* subsp. *stamineus* is locally common in a number of areas in the Blue Mountains. It is spread by seed movement. *Bromus catharticus* subsp. *stamineus* is also naturalised in Victoria, Tasmania and South Australia (Walsh in Walsh & Entwisle 1994, as *B. lithobius* and *B. cedabilla*; Morris in Curtis & Morris 1994, as *B. fonkii*; Jessop in Barker et al. 2005, as *B. lithobius*).

Eragrostis trichophora Coss & Durieu

Hairy Love Grass

Description: Tufted perennial grass to 0.6 m high. See van Oudtshoorn (1992).

Region of Origin: Native of Botswana, Lesotho, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe.

New South Wales Distribution / Habitats: North Western Slopes, North Western Plains. In South Africa this species prefers sandy to sandy loam soils and is often common in disturbed areas such as roadsides (van Oudtshoorn 1992). These are the habitats occupied by this grass around Narrabri, Gravesend and Walgett.

First Record: Roadside – Newell Highway, 13 km SW of Narrabri, *A. Storrie 03/01*, 14 Apr 2003 (NSW).

Additional Records: Roadside – Collarenebri Road, 10 km W of Moree, *A. Storrie 03/02*, 16 Apr 2003 (CANB, MEL, NSW); rail crossing, Narrabri, *A. Storrie 04/03*, 10 Jul 2003 (CANB, BRI); Roadside – Newell Highway, 6 km SW of Narrabri, *A. Storrie 02/04 & T. Farrell*, 10 Feb 2004 (MEL, NSW, PRE); Roadside – Gwydir Highway, 1 km E of the village of Gravesend, *A. Storrie 09/04*, 3 Mar 2004 (CANB, NSW, PRE); roadside 20 m north of the junction of Kopi and Gem Streets, Lightning Ridge, *J.R. Hosking 2640*, 3 Nov 2005 (CANB, MEL, NE, NSW, PRE); other specimens from nearby locations are not listed.

Notes: This grass is spread by seed movement and sometimes locally by stolons. It was not collected until 2003 but was abundant by this time. This grass is similar in appearance

to *Eragrostis curvula* and is likely to be mistaken for that species. *Eragrostis trichophora* is considered to be a grass of average grazing value, as is *E. curvula*, in South Africa (van Oudtshoorn 1992). In *Flora Zambesiaca* this species is included in *Eragrostis cylindriflora* Hochst. by Cope in Pope (1999): 'In the Flora Zambesiaca area, however, the distinctions [between species] break down with all elements completely intergrading'. This species is also naturalised in the Northern Territory (*Albrecht 10568* – CANB) and in Maryland, USA (Peterson in Morin 2003).

Dicotyledons

ACANTHACEAE

Acanthus mollis L.

Bear's Breech

Description: Herb with inflorescence to 2 m high. See Barker in Jessop & Toelken (1986).

Region of Origin: Native of southern Europe (Spain east to the former Yugoslavia), Mediterranean islands, northern Africa (Morocco, Algeria, Tunisia), Asia (Turkey, Syria) and the Canary Islands.

New South Wales Distribution / Habitats: Central Tablelands and Central Coast. Only collected from disturbed *Eucalyptus piperita* and *Corymbia gummifera* sclerophyll forest where it was found growing with *Genista monspessulana*. Also observed growing as a garden escape in North Rocks, Sydney.

First Record: Southern side of Great Western Highway, 1.4 km south east of junction with Tableland Road, between Bullaburra and Wentworth Falls, *J.R. Hosking 2239*, 25 Feb 2002 (AD, CANB, MEL, NE, NSW).

Notes: Barker (1986) suggests the species that is cultivated and naturalised in Australia may be intermediate between *A. mollis* and *A. spinosus* L. Most plants grow near existing plants or where garden waste has been dumped. Spread is likely to be vegetative. In the collection area there were more than 100 plants over an area of c. 30 m x 4 m. This species is also naturalised in Queensland, Victoria, Tasmania, South Australia and possibly in Western Australia (Bean in Henderson 2002, Ross & Walsh 2003, Rozefelds et al. 1999, Barker 1986, Hussey et al. 1997). It is also naturalised in New Zealand (Sykes in Webb et al. 1988).

Justicia caudata A.Gray

Description: Rhizomatous shrub to 1.1 m high. See Gibson (1974) and Curtis (1796, as *Justicia peruviana* L.).

Region of Origin: Native of America (Mexico to South America) and to Caribbean islands.

New South Wales Distribution / Habitats: North Coast. Grows in coastal sandy areas where garden refuse has been dumped. According to Gibson (1974), this species grows in damp thickets in Guatemala.

First Record: Alongside southern end of Owen Street in Macquarie Nature Reserve, Port Macquarie, *J.R. Hosking 2224*, 1 Oct 2002 (AD, CANB, MEL, NE, NSW).

Notes: Also known to be naturalised at Nambucca Heads between Captain Cook Lookout and the town on the southern side of the road (also from dumped garden waste) in weed-infested native vegetation. In horticulture, this species is often referred to *Justicia peruviana* Lam. sensu Curtis (Curtis 1796). According to T. Daniels (CAS; pers. comm.), there is confusion regarding the name that should be applied to *J. peruviana* Lam. *sensu* Curtis. At present, he uses the name *J. candata* for this species but recognises that there are likely to be earlier valid names. This species appears to be spreading by rhizomes from dumped garden waste. *Justicia candata* is not known to be naturalised elsewhere in Australia.

Odontonema tubaeforme (Bertol.) Kuntze [syn. *Odontonema strictum* (Nees) Kuntze]

Fire Spike

Description: Rhizomatous shrub with erect stems to 2 m high. See Barker (1996) and Hooker (1848, as *Thyrsacanthus strictus* Nees).

Region of Origin: Native of Panama, Nicaragua, Honduras, Costa Rica, Belize and Mexico.

New South Wales Distribution / Habitats: North Coast, Central Coast and Lord Howe Island. Locations where the species has been collected are where garden waste had been dumped. These areas are on the edge of disturbed tall open forest. In the first collection area *O. tubaeforme* was growing with *Delairea odorata*, *Monstera deliciosa*, *Lantana camara*, *Cinnamomum camphora* and native trees and shrubs.

First Record: Native vegetation opposite 109 Pacific Drive, Port Macquarie, *J.R. Hosking 2195*, 25 Feb 2002 (AD, CANB, MEL, NE, NSW).

Additional Record: Gully in front of 32 Mitchells Pass Road, Blaxland, *C.H. Barker 55 & L. Thomas*, 30 May 2004 (CANB, MEL, NE, NSW).

Notes: This species is commonly known in horticulture as *Justicia coccinea* but this name refers to what is now known as *Pachystachys coccinea* (Aubl.) Nees. Many publications refer to *O. tubaeforme* as *O. strictum* but *O. tubaeforme* is believed to be the name that should be applied to this species (Barker 1996). There is an earlier specimen of *O. tubaeforme* held at NSW (*E. McBarron s.n.*, 27 August 1969), but there is no indication that the specimen was from naturalised plants. Apart from four clumps growing in native woodland where *J.R. Hosking 2195* was collected, there were many hundreds of stems recorded within Macquarie Nature Reserve at Port Macquarie (information recorded on label for *J.R. Hosking 2195*). This species appears to be spreading vegetatively, initially reaching areas via dumped garden waste. Vegetative

spread is reported as the main means of spread on Pacific islands (Meyer & Lavergne 2004). *Odontonema tubaeforme* has also been observed in Hunt's Creek Reserve at North Rocks and remnant bushland at Pennant Hills, Sydney and is recorded as naturalised in Queensland (Cook and Moreton pastoral districts) (Bean in Henderson 2002) with the first naturalised specimen (*Sharpe 4302 & Batianoff* – BRI) collected from Noosa National Park, Noosa in March 1986 (Barker 1996). This species is naturalised on Lord Howe Island (*Batianoff 200311*, *Le Cussan 1128* – both BRI) and is widely naturalised in French Polynesia, Hawaii and Samoa where it forms dense monospecific stands (between 100 and 500 m^2 in area) in wet forests (Meyer & Lavergne 2004).

Ruellia squarrosa (Fenzl) Cufod.

Creeping Ruellia

Description: Shrub to 40 (rarely to 100) cm high. See Barker (1996) and Walker (1970).

Region of Origin: Native of southern Mexico.

New South Wales Distribution / Habitats: Central Coast. Only collected from a gully in *Syncarpia glomulifera*, *Allocasuarina torulosa* and *Angophora costata* forest. Observed in Hunt's Creek Reserve in North Rocks, Sydney, growing in shaded creekside areas. Also recorded from shady situations in Queensland (Barker 1996).

First Record: Bushland Park off Ronald Avenue, Lane Cove, *V. Klaphake 936*, 7 Dec 1993 (NSW).

Additional Record: Alongside Maraket Avenue, Blaxland, *J.R. Hosking 2218 & C.H. Barker*, 24 Apr 2002 (AD, CANB, MEL, NE, NSW).

Notes: There were a few plants seen at each location. According to Meyer & Lavergne (2004) this species spreads by seed and vegetatively. The species is also recorded as naturalised in south eastern Queensland (Moreton pastoral district) (Bean in Henderson 2002) with the first naturalised specimen (*Pedley 5307* – BRI) collected at Indooroopilly in November 1984 (Barker 1996). *Ruellia squarrosa* is also naturalised in Okinawa and La Réunion (Walker 1976, Meyer & Lavergne 2004).

Stephanophysum longifolium Pohl [syn. *Ruellia brevifolia* (Pohl) C.Ezcurra, *Ruellia graecizans* Backer]

Tropical Wild Petunia

Description: Herb to 1 m high. See Barker (1986) & Everett (1982).

Region of Origin: Native of Brazil.

New South Wales Distribution / Habitats: North Coast. At Bellingen this species is abundant in shaded areas, but also occurs in exposed areas.

First Record: Naturalised in Bellingen Hospital grounds, Bellingen, *J.R. Hosking 2267 & I. Turnbull*, 13 Mar 2003 (AD, CANB, MEL, NE, NSW).

Notes: In the Bellingen Hospital grounds this species grows as the dominant understorey plant over an area of 110 m by 20–50 m. It disperses by seed. The species was also scattered over neighbouring properties, including in a pine plantation across Kalang Road from Bellingen Hospital. Since this species is an attractive ornamental, it is likely to be widely planted. It is also recorded as naturalised in Queensland (Cook and Moreton pastoral districts) (Bean in Henderson 2002) with the first naturalised specimen (*Lanham 590* – BRI) collected from 3.2 km north of Nambour in January 1973 (Barker 1986). This species is also naturalised in disturbed areas in Hawaii, Fiji, La Réunion and Mauritius (Meyer & Lavergne 2004). In La Réunion it is estimated to have invaded 3000 ha of wet forests (Meyer and Lavergne 2004).

Strobilanthes anisophylla (G.Lodd.) T.Anderson

Goldfussia

Description: Shrub to 1.3 m high. See Hooker (1885), Everett (1982) and Spencer (2002).

Region of Origin: Native of India (Meghalaya, West Bengal) and Bhutan.

New South Wales Distribution / Habitats: Central Coast. Only known from Lapstone where it grows in sandy soil in the bed of an intermittent stream in a gully forest with *Ligustrum sinense*, *Lantana camara*, *Lomandra* sp., *Morinda jasminoides*, *Ochna serrulata*, *Allocasuarina torulosa*, *Cinnamomum camphora* and *Corymbia gummifera*.

First Record: Gully north of northern part of Hume Road, Lapstone, *J.R. Hosking 2331 & C.H. Barker*, 21 Aug 2003 (AD, CANB, MEL, NE, NSW).

Additional Record: Gully north of northern part of Hume Road, Lapstone, *J.R. Hosking 2412*, 6 Dec 2003 (AD, CANB, MEL, NE, NSW).

Notes: Only recorded from four plants (all flowering in August 2003) occurring in a gully in Lapstone; a later collection (in December 2003) from the same location had the remains of flowers but no fruit. Although this species may have reached the site via movement of vegetative material down the gully, it has been observed to naturalise freely near garden plantings in nearby Glenbrook. The species is an attractive ornamental and is likely to be widely planted. *Strobilanthes anisophylla* was at one time referred to *Goldfussia* but Bremekamp's division of *Strobilanthes* into many segregate genera is no longer accepted (Wood 1994). This species is regarded as doubtfully naturalised in Queensland based on collections from Eagle Heights, Mount Tambourine in September 2000 (*Bean 16817* – AD, BRI, NSW) where a group of less than 10 plants that did not appear to have been cultivated was growing with native rainforest shrubs near the edge of the road (A. Bean pers. comm., Nov 2004) and from Montville, inland from the Sunshine Coast, in June 2005 where about 30 plants were growing in a gully of regrowth rainforest (*Batianoff 0506006* – BRI & G. Batianoff pers. comm., Nov 2005). *Strobilanthes anisophylla* is not known to be

naturalised elsewhere in Australia. The speeies is reeorded as naturalised in native bush, gardens and among other weeds in North Auekland, New Zealand (Heenan et al. 2004).

AIZOACEAE

Drosantheuuum candens (Haw.) Schwantes [*Drosanthemum floribundum* (Haw.) Schwantes misapplied]

Redondo Creeper

Deseription: Suceulent, prostrate to weakly ereet, shrub. See Jessop in Jessop & Toelken (1986), Walsh in Walsh & Entwisle (1996) and Hartmann (2002).

Region of Origin: Native of South Afriea (Cape Provinee).

New South Wales Distribution / Habitats: South Coast. Only known in N.S.W. from Bowen Island, Jervis Bay.

First Reeord: Bowen Island, Jervis Bay, *R.J. Rudd 165*, 22 Jan 1992 (CANB).

Notes: This speeies is grown as an ornamental and is spread by seed. It is also naturalised in Vietoria, South Australia and Western Australia (Walsh in Walsh & Entwisle 1996, Jessop in Jessop & Toelken 1986, Hussey et al. 1997).

ASCLEPIADACEAE

Stapelia gigantea N.E.Br.

Dead Horse Plant

Deseription: Mat-forming herb to 50 em high. See Wagner et al. (1999), Spencer (2002) and Fabian & Germishuizen (1999).

Region of Origin: Native of southern Afriea.

New South Wales Distribution / Habitats: North Western Plains. Known from a number of loeations in and around Lightning Ridge where it is found growing below trees and shrubs, often as the dominant speeies.



Fig. 1. *Stapelia gigantea* has large flowers that attract blowflies for pollination. This succulent is spreading via wind-dispersed seed in the Lightning Ridge area.

First Reeord: East of a point 3.2 km along 3 Mile Road from Lightning Ridge end, *J.R. Hosking 2338 & W. Schofield*, 3 Sep 2003 (AD, BRI, CANB, MEL, NE, NSW).

Additional Reeord: East of a point 3.2 km along 3 Mile Road from Lightning Ridge end, *J.R. Hosking 2404 & W.A. Cherry*, 26 Nov 2003 (AD, BRI, CANB, MEL, NE, NSW).

Notes: This is a loeally dominant naturalised herb. The speeies tolerates hot and dry eonditions and is used as an ornamental on the opal fields around Lightning Ridge. The plant is pollinated by blowflies that are attraeted to the foul-smelling flowers (hence the eommon name). Seeds of this speeies are wind-dispersed. It is reported as naturalised in Queensland, South Australia and Hawaii (Forster in Henderson 2002, AD speeimen, Wagner et al. 1999).

ASTERACEAE

Calyptocarpus vialis Less.

Creeping Cinderella Weed

Deseription: Herb with ereet to trailing stems. See Stanley & Ross (1986) and Riekett (1973).

Region of Origin: Native to Mexieo, El Salvador and Honduras.

New South Wales Distribution / Habitats: North Western Plains. Only known from a lawn in Moree. Also likely to be a weed of lawns in the North Coast region of N.S.W.

First Reeord: 134 Heber Street, Moree, *T. Holmes s.n.*, 13 Aug 2002 (NSW).

Notes: Awns on the fruit aid in dispersal of this speeies. It was eolleeted from a lawn where over 100 plants were present. This speeies is listed as a weed of gardens, footpaths and other areas in south eastern Queensland (Stanley & Ross 1986). It is now eommon in lawns in Brisbane. The first herbarium speeimen for Queensland (*Everist 2582* – BRI) was eolleeted at Toowong, Brisbane, in April 1946. *Calyptocarpus vialis* is spreading to eentral eoastal Queensland (Roekhampton, Heron Island and the Whitsunday region) and is eonsidered to be invasive in the understorey of riparian forests in eentral Queensland (G. Batianoff pers. eomm., Nov 2005). It is likely to be a weed of disturbed areas in N.S.W. and is probably present on the N.S.W. north eoast. However, so far it has not been eolleeted from this area. This speeies is also naturalised in south eastern USA and Hawaii (Riekett 1973, Wagner & Herbst 1999).

Eupatoriuu liudleyanum DC.

Joe Pye Weed, Boneset

Deseription: Herb to 1 m high. See Makino (1964), Ohwi (1965) and Li in Li et al. (1978a).

Region of Origin: Native of China, Japan, Taiwan and the Philippines.

New South Wales Distribution / Habitats: North Coast, Northern Tablelands. In Cunnawarra National Park it is

recorded from a sphagnum/sedge community on peat. In Japan and Taiwan, this species grows in wet grassy places and on low mountains (Ohwi 1965, Li in Li et al. 1978a).

First Record: In swamps near the Tweed River, *Carron & Moore s.n.* (collector not listed on specimen, specimen not dated but pre-1865 – MEL) (Auld 1977)).

Additional Records: Timbarra, *Stuart s.n.*, no date (pre-1896 – MEL); Petroi Plateau, south of New England National Park, *J.B. Williams s.n.*, 5 Feb 1974 (NE, NSW); 'Petroi', on west-flowing creek, 350–400 m upstream from bridge crossing near old dwelling, Cunnawarra National Park, *W. Cherry 479 & 480 & A.J. Perkins*, 12 Apr 2003 (K, L, MO, NSW).

Notes: Early specimens of this species are held in the National Herbarium of Victoria (MEL) and information regarding these is covered in Auld (1977). He suggests that the species may have been introduced by Chinese labourers to the gold mining area of Timbarra. This species is dispersed by seed. According to recent collections (*Cherry 479, 480 & Perkins* – NSW) there were about six plants in the collection area in Cunnawarra National Park.

Hieracium aurantiacum L. subsp. ***carpathicola*** Nägeli & Peter

Orange Hawkweed

Description: Herb to 15 (rarely to 40) cm high. See Garnock-Jones in Webb et al. (1988), Espie (2001), Royer & Dickinson (1999) and Whitson et al. (1991).

Region of Origin: Native of Europe.

New South Wales Distribution / Habitats: Southern Tablelands. Occurs in a sub-alpine area in Kosciuszko National Park.

First Record: Kosciuszko National Park, Round Mountain Fire Trail, c. 4 km by road from Tooma Road, c. 2 m west of track margin, *N. Walsh 5931, K. McDougall & G. Wright*, 17 Dec 2003 (CANB, MEL, NSW).

Notes: This species is dispersed by seed and spreads locally via rhizomes and stolons. The initial collection was from a patch of about one metre square. Later surveys showed that this species occurred over more than 1 ha and seem to indicate that the species had been present for some time. *Hieracium aurantiacum* subsp. *carpathicola* is also naturalised in Tasmania, particularly on roadsides (Curtis 1963, as *Hieracium brunneocroceum* Pugsley) and in Victoria in and around Falls Creek, Mt Hotham and Mt Buller. Attempts are being made to eradicate the species in N.S.W. and Victoria. It is also a weed in New Zealand, Canada and the USA (Espie 2001, Royer & Dickinson 1999, Whitson et al. 1991). For more information on this species refer to Garnock-Jones in Webb et al. (1988), Espie (2001) and Royer & Dickinson (1999).

BIGNONIACEAE

Tabebuia chrysotricha (Mart. ex DC.) Standl.

Description: Tree to 15 m high. See Sandwith & Hunt (1974) and Lorenzi (1992).

Region of Origin: Native of north eastern Argentina and Brazil.

New South Wales Distribution / Habitats: North Coast. On well-drained red earth soils in a high rainfall area at Bellingen.

First Record: Naturalised in Bellingen Hospital grounds, Bellingen, *J.R. Hosking 2268 & I. Turnbull*, 13 Mar 2003 (CANB, MEL, NE, NSW).

Notes: Spread by wind-dispersed seed. Only known to have naturalised at Bellingen, not known to be naturalised elsewhere in Australia or overseas.

Tabebuia impetiginosa (Mart. ex DC.) Standl.

Description: Shrub or small tree to 6 m high. See Gentry in Steyermark et al. (1997) and Lorenzi (1992).

Region of Origin: Native of America (Mexico to Peru, north western Argentina, Paraguay and Brazil).

New South Wales Distribution / Habitats: North Coast. On well-drained red earth soils in a high rainfall area at Bellingen.

First Record: Naturalised in Bellingen Hospital grounds, Bellingen, *J.R. Hosking 2273 & I. Turnbull*, 14 Mar 2003 (CANB, MEL, NE, NSW).

Notes: This species is spread by wind-dispersed seed. Only known to have naturalised at Bellingen, Not known to be naturalised elsewhere in Australia or overseas.

BOMBACEAE

Ceiba speciosa (A.St.-Hil., A.Juss. & Cambess.) P.Ravenna [syn. *Chorisia speciosa* A.St.-Hil.]

Chorisia

Description: Tree to over 20 m high. See Santos (1967), Little et al. (1974) and Lorenzi (1992).

Region of Origin: Native of Argentina, Brazil and Paraguay.

New South Wales Distribution / Habitats: North Coast. On well-drained red earth soils in a high rainfall area at Bellingen.

First Record: Naturalised in Bellingen Hospital grounds, Bellingen, *J.R. Hosking 2272, I. Turnbull & T. Scanlon*, 14 Mar 2003 (CANB, MEL, NE, NSW).

Notes: Although we have included this species in the family Bombaceae, recent molecular evidence suggests that this family is part of the Malvaceae, as the subfamily Bombacoideae (Stephens 2005). At Bellingen, there were

more than 30 small plants growing to 2 m high. These plants arose via seed from trees that were planted in 1965 and 1970. Therefore it appears that these plants will take time to reach the reproductive stage. *Ceiba speciosa* is not known to be naturalising elsewhere in Australia or overseas.

BRASSICACEAE

Hesperis matronalis L.

Dame's Violet

Description: Herb to 1 (rarely to 1.5) m high. See Rich (1991), Garnock-Jones in Webb et al. (1988), Stubbendieck et al. (1995) and Royer & Dickinson (1999).

Region of Origin: Native from southern Europe to western Siberia.

New South Wales Distribution / Habitats: Central Tablelands. Collected from woodland alongside the Jenolan River below Jenolan Caves and scattered plants observed in woodland above Jenolan Caves House.

First Record: Campsite Jenolan Caves, *G.R. Sainty s.n.*, 17 Jan 1989 (NSW).

Additional Record: Alongside Jenolan River downstream of sewage works, below Jenolan Caves, *J.R. Hosking 2212*, 23 Apr 2002 (CANB, MEL, NE, NSW).

Notes: This species is dispersed by seed. It has attractive purple flowers and it is surprising that it has not been collected a number of times from this well-collected locality. Hundreds of naturalised plants are scattered over more than 1 km of river frontage including through a camping area. This species is naturalised in a number of other countries but appears to mainly occur on waste ground (Garnock-Jones in Webb et al. 1988, Rich 1991, Stubbendieck et al. 1995, Royer & Dickinson 1999).

CACTACEAE

Cereus uruguayanus R.Kiesling

[basionym for *Cereus hildmannianus* K.Schum. var. *uruguayanus* (R.Kiesling) N.P.Taylor]

Peruvian-apple

Description: Columnar cactus to 10 m high. See Anderson (2001, as *C. hildmannianus* var. *uruguayanus*).

Region of Origin: Native of Argentina, Brazil and Uruguay.

New South Wales Distribution / Habitats: North Western Slopes and North Western Plains. Naturalised in woodland in areas near original plantings.

First Record: Near cattle grid where road to Glen Garry leaves the Grawin road at right angle, *J.R. Hosking 2400 & W.A. Cherry*, 25 Nov 2003 (B, BRI, CANB, MEL, NE, NSW, SI).

Additional Record: Alongside Wandobah Road, south west of Gunnedah, *J.R. Hosking 2528 & G.W. Carr*, 12 Nov 2004 (CANB, MEL, NE, NSW).

Notes: This cactus was common in the initial collection area with hundreds of plants of all ages occurring for many square kilometres in and around the opal mining town of Grawin. Near Gunnedah only six plants from seedlings to adult plants to 4 m high were seen but others are likely to be present. This species is spread by seed. It is also naturalised in Queensland in the Darling Downs, Leichhardt and Maranoa pastoral districts (Forster in Henderson 2002, *Batianoff 2112298GNB, 2112318GNB* – BRI) and in the Northern Territory (DNA, MEL, NT specimens). This cactus is naturalised in Hawaii and South Africa (Wagner et al. 1999, Bromilow 1995 as *Cereus peruvianus* Mill. misappl.).

Cylindropuntia fulgida (Engl.) F.M.Knuth var. ***mamillata*** (A.Schott ex Engl.) Backeb. forma ***monstrosa*** (J.M.Coult.) P.V.Heath

Boxing Glove Cactus, Coral Cactus

Description: Cactus to 75 cm high. See Earle (1980).

Region of Origin: Native of the USA (Arizona).

New South Wales Distribution / Habitats: North Western Plains and North Far Western Plains. In woodland in areas near original plantings and where segments have spread and then grown.

First Record: Cumborah behind abandoned garage, W of Grawin – Walgett and Lightning Ridge road junction, *J.R. Hosking 1888, J.P., T.L. & G.R. Hosking*, 18 Sep 2000 (CANB, MEL, NE, NSW).

Additional Records: Alongside Grawin golf course, *J.R. Hosking 2406 & W.A. Cherry*, 27 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD); Purnamoota Station, the Springs Paddock, c. 25 km NE of Broken Hill, *M. Fletcher s.n.*, 5 Jan 2004 (NSW).

Notes: Locally common cactus with hundreds of plants of all ages occurring for many square kilometres in and around Broken Hill, Cumborah, Grawin and Lightning Ridge. This form of *C. fulgida* var. *mamillata* occurs naturally in Pinal and Pima Counties in Arizona and in this area flowers and fruit have never been observed (Earle 1980). This also appears to be the case in Australia where spread seems to be via movement of segments, particularly by water. As with a number of other *Cylindropuntia* species, this cactus is likely to be damaged by the cochineal insect *Dactylopius tomentosus* (Lamarck). This cactus is also naturalised in Queensland, South Australia and Western Australia (BRI, AD, PERTH and NSW specimens).

Cylindropuntia prolifera (Engl.) F.M.Knuth

Description: Cactus to 1.5 m high. See Benson (1982) and Anderson (2001).

Region of Origin: Native of the USA (California) and Mexico (Baja California).

New South Wales Distribution / Habitats: North Western Plains. Naturalised in woodland in areas near original plantings around Lightning Ridge.

First Record: approximately 9 km north of Broken Hill alongside Nine Mile Road on Nine Mile Station, *S. Lewer, s.n.*, 24 April 1993 (NSW).

Additional Records: Start of road to 9 Mile Opal Field, Lightning Ridge, *J.R. Hosking 2402 & W.A. Cherry*, 25 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD).

Notes: This cactus is scattered in a number of locations in and around Lightning Ridge and to the north of Broken Hill. It appears to be spread by movement of segments. According to Pinkava in Morin (2004) this cactus is of hybrid origin. As with a number of other *Cylindropuntia* species, this cactus is likely to be damaged by the cochineal insect *Dactylopius tomentosus*. *Cylindropuntia prolifera* has also been recorded from the town common at Longreach, Queensland in August 2006 (*B. Carlson s.n.* –BRI). It is not known to have naturalised in other countries.

Cylindropuntia tunicata (Lehm.) F.M.Knuth

Description: Small shrub cactus to 60 cm high. See Swinbourne in Jessop & Toelken (1986), Stajsic & Carr in Walsh & Entwisle (1996), Benson (1982) and Anderson (2001). In the first three references this species is under the name *Opuntia tunicata* (Lehm.) Link & Otto.

Region of Origin: Native of Mexico, the USA (Texas) and Cuba.

New South Wales Distribution / Habitats: North Western Plains. Naturalised in woodland in areas near original plantings in and around Grawin.

First Record: Western end of Grawin, near Museum site, *J.R. Hosking 2398 & W.A. Cherry*, 25 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD).

Notes: This cactus is scattered over a number of hectares in and around Grawin. It is not known to be naturalised elsewhere in N.S.W. This species was reported in Hosking et al. (2003) but material referred to that species has since been determined to represent *Cylindropuntia rosea* (see later in this paper). *Cylindropuntia tunicata* appears to be spread by the movement of its segments. Seed is produced, but this does not appear to be a source of dispersal as fruit does not appear to be eaten by Australian animals and seed does not separate from fruit. As with a number of *Cylindropuntia* species this cactus is damaged by the cochineal insect *Dactylopius tomentosus*. *Cylindropuntia tunicata* as circumscribed here is the same species as the one recorded under this name in Victoria (Stajsic & Carr in Walsh & Entwisle 1996) and is probably the same as the one under this name in South Australia (Swinbourne in Jessop & Toelken 1986). In Victoria the first specimen was collected from Natya (between Swan Hill and Robinvale), *A. Carter s.n.*, 18 Aug 1994 (MEL) and in South Australia the first specimen was collected from the Barmera region, *C. Schrank s.n.*, Aug 1980 (AD). This species is also naturalised in Chile and Ecuador (Anderson 2001, Pinkava in Morin 2004).

CISTACEAE

Cistus salviifolius L.

Sage-leaf Rock Rose, Sage-leaved Cistus

Description: Shrub to 1 m high. See Coode in Davis (1965), Polunin (1969), Spencer (1997) and Clarke (2005).

Region of Origin: Native of Africa (Algeria, Libya, Morocco, Tunisia), Asia (Turkey) and southern Europe (from Greece to Portugal).

New South Wales Distribution / Habitats: Southern Tablelands. Plants at the Black Mountain site are growing in a disturbed site adjacent to an abandoned road bordering disturbed woodland of *Eucalyptus dives*, *E. mannifera* and *E. melliodora*. Plants at the Lake Burley Griffin site were recorded growing in a *Quercus suber* plantation.

First Record: Black Mountain Reserve: SW margin, near Caswell Drive, *L.G. Adams 4080*, 2 Nov 1988 (CANB).

Additional Records: Canberra, Stromlo Forest, N bank of Lake Burley Griffin near Scrivener Dam, *I.R. Telford 11511*, Nov 1991 (CANB); end of Rani road, SW slope of Black Mountain, Canberra, *B.J. Lepschi 4236, T.R. Lally & B.R. Murray*, 11 Nov 1999 (CANB, AD, K, MEL, MO, NSW); end of Rani road, SW slope of Black Mountain, Canberra, *B.J. Lepschi 5060*, 11 Jan 2004 (CANB, AD, MEL, NSW).

Notes: This species is spread by seed. There were approximately 50 plants covering an area about 5 m x 20 m at the Black Mountain site in 2004. The population at the Lake Burley Griffin site (*Telford 11511*) is described by the collector as 'rare – two small patches observed'. The origin of plants is unknown, but they may have originated from discarded garden refuse. This species is also naturalised in Victoria (Clarke 2005) and California (McClintock in Hickman 1993).

CORNACEAE

Cornus capitata Wall. [*Dendrobenthamia capitata* (Wall.) Hutch.]

Himalayan Strawberry-tree, Evergreen Dogwood

Description: Tree to 15 m high. See Jeanes in Walsh & Entwisle (1999), Blood (2001) and Webb in Webb et al. (1988, as *Dendrobenthamia capitata* (Wall.) Hutch.).

Region of Origin: Native of China, Bhutan, India (Assam, Punjab) and Myanmar.

New South Wales Distribution / Habitats: Central Tablelands. Becoming widespread in disturbed native vegetation in the upper Blue Mountains.

First Record: Narrow remnant of native vegetation between Glenwattle Close and Carlton Street, north of Wellington Road, Katoomba, *C.H. Barker 17 & J.R. Hosking*, 3 Dec 2003 (CANB, MEL, NE, NSW).

Notes: Collection notes indicate that the specimen came from a single naturalised flowering and fruiting plant 4 m high, and that there are many more non-reproductive plants growing amongst native vegetation in Gordon Falls Reserve, and seattered plants elsewhere in remnant native vegetation throughout higher parts of the Blue Mountains. This species is spread by bird-dispersed seed. *Cornus capitata* is also recorded as naturalised in Victoria with the first naturalised specimen (*Walsh 3503* – CANB, MEL) collected in Sherbrooke Forest in the Dandenong Ranges in May 1993. The species is now present in large numbers in native vegetation in the Dandenong Ranges. This tree is not recorded as naturalised in other Australian states but is naturalised in New Zealand (Webb in Webb et al. 1988).

CRASSULACEAE

Bryophyllum daigremontianum (Raym.-Hamet & H.Perrier) A.Berger

Mother-of-millions

Description: Herb to 45 cm high. See Stanley & Ross (1983) and Spencer (2002).

Region of Origin: Native of Madagascar.

New South Wales Distribution / Habitats: North Western Plains. Naturalised in woodland near plantings of this species.

First Record: West of road 3.0 km along 3 Mile Road from Lightning Ridge end, *J.R. Hosking 2343*, 4 Sep 2003 (BRI, CANB, MEL, NE, NSW).

Notes: In the Lightning Ridge area this species is naturalised in a number of locations but is not as common as either *Bryophyllum delagoense* or *B. daigremontianum* x *B. delagoense*. *Bryophyllum daigremontianum* spreads via movement of plantlets and seed (Hannan-Jones & Playford 2002). As with other *Bryophyllum* species this species is toxic to stock (Hannan-Jones & Playford 2002). It has not been collected from elsewhere in N.S.W. It has also been recorded as naturalised in Queensland from the Moreton, North Kennedy and South Kennedy pastoral districts (Forster in Henderson 2002, there is no specimen from Cook pastoral district – G. Batianoff pers. comm., Dec 2005). This *Bryopyllum* is naturalised in Hawaii and Florida (Lorence et al. 1995, Wunderlin & Hansen 2004). *Bryophyllum* spp. are the subject of a biological control program (Hannan-Jones & Playford 2002). For more information on *Bryoplyllum* spp. see Hannan-Jones & Playford (2002).

Bryophyllum fedtschenkoi (Raym.-Hamet & H.Perrier) Lauz.-March.

Description: Herb to 60 cm high. See Spencer (2002).

Region of Origin: Native of Madagascar.

New South Wales Distribution / Habitats: North Western Slopes. Naturalised in *Callitris glaucophylla* woodland that is also infested with *Bryophyllum daigremontianum* x *B. delagoense*.

First Record: Warialda, *C. McLeod s.n.*, 8 Jul 2002 (NSW).

Notes: In 2004, the site was revisited with C. McLeod. At this time there were large numbers of plants spread around the collection area although the area infested was only a few hundred square metres. *Bryoplyllum fedtschenkoi* spreads via movement of plantlets and seed (Hannan-Jones & Playford 2002). As with other species of *Bryophyllum*, this species is likely to be toxic to stock. *Bryophyllum fedtschenkoi* has not been recorded as naturalised elsewhere in N.S.W., but it is naturalised in Queensland and South Australia (Forster in Henderson 2002, Toelken in Barker et al. 2005). This species is also naturalised in Hawaii (Lorence et al. 1995). Species of *Bryoplyllum* are the subject of a biological control program in Australia (Hannan-Jones & Playford 2002).

ELAEAGNACEAE

Elaeagnus umbellata Thunb.

Autumn Olive

Description: Shrub to 7 m high. See Makino (1964), Ohwi (1965) and Ohba in Iwatsuki et al. (1999).

Region of Origin: Native from Afghanistan to China, Korea and Japan.

New South Wales Distribution / Habitats: Central Tablelands. Naturalising at Lawson where it is growing with native and other exotic species.



Fig. 2. *Cylindropuntia prolifera* is one of the many *Cylindropuntia* species naturalised in opal field areas of northern N.S.W.

First Record: Wilson Park, near Lawson Pool, Lawson, *C.H. Barker 31*, 27 Sep 2003 (CANB, MEL, NE, NSW).

Additional Records: Wilson Park, near Lawson Pool, Lawson, *C.H. Barker 24* & *J.R. Hosking*, 4 Dec 2003 (CANB, MEL, NE, NSW).

Notes: Known from three plants at Lawson and one of these may have been planted. Spread by bird-dispersed seed. The species is not recorded as naturalised elsewhere in Australia. This species is considered to be a weed, forming impenetrable thickets in a number of areas in mainland USA and is naturalised and spreading in Hawaii (Sternberg in Randall & Marinelli 1996, Wagner et al. 1999).

ERICACEAE

Arbutus unedo L.

Strawberry Tree

Description: Tree to 8 (rarely to 12) m high. See Jessop in Jessop & Toelken (1986), Walsh in Walsh & Entwisle (1996) and Blood (2001).

Region of Origin: Native of southern Europe, Ireland, Turkey and northern Africa.

NEW SOUTH WALES DISTRIBUTION / HABITATS: Central Tablelands. Collected from Blackheath where it is growing in disturbed dry sclerophyll forest with many exotic species on sandstone-derived sandy soil.

First Record: Gully between two sections of Thirroul Street, Blackheath, *J.R. Hosking 2295* & *C.H. Barker*, 27 Mar 2003 (CANB, MEL, NE, NSW).

Notes: Three naturalised plants were visible at the collection site but the species is widely naturalised in low numbers in upper parts of the Blue Mountains. There is also a record of a single, apparently naturalised, plant growing in the Australian Capital Territory (O'Connor Hill, 100 m N of bike track, *M. Mulvaney ANU 30022*, 8 January 1986 – CANB). This species is dispersed by birds and foxes that consume fruit and deposit seed in droppings and seats (Blood 2001). This tree is naturalised in Victoria and South Australia (Walsh in Walsh & Entwisle 1996, Jessop in Jessop & Toelken 1986) and doubtfully naturalised in Queensland (*Sharpe s.n.* – BRI). It is naturalised in New Zealand and the British Isles (Sykes in Webb et al. 1988, Stace 1997). *Arbutus unedo* produces lignotubers that enable plants to survive destruction of above-ground parts, for example by fire (Blood 2001).

Rhododendron ponticum L.

Rhododendron

Description: Large shrub to 8 m high. See Sykes in Webb et al. (1988) and Cronk & Fuller (1995).

Region of Origin: The species occurs as disjunct populations in south western Europe (Portugal, Spain), south eastern Europe (south eastern Bulgaria, Turkey) and western Asia (Georgia, Lebanon, Krasnador, Turkey).

New South Wales Distribution / Habitats: Central Tablelands. Collected from *Eucalyptus oreades* and *E. mannifera* wet sclerophyll forest with an understorey of *Gahnia* sp., *Gleichenia* sp., *Acacia longifolia* subsp. *longifolia*, *Cyathea leichhardtiana*, *Polyscias sambucifolia*, *Ilex aquifolium* and *Arbutus unedo* on sandstone-derived sandy soil with high levels of organic matter.

First Record: 193 Hat Hill Road, Blackheath, *C.H. Barker 3* & *J.R. Hosking*, 25 Nov 2002 (CANB, MEL, NE, NSW).

Notes: Two flowering naturalised plants were present at the collection site but the species is naturalised in low numbers throughout the upper Blue Mountains. The largest known naturalised population in North Katoomba consists of several hundred plants. *Rhododendron ponticum* is naturalised in the Queenstown and Strahan areas of Tasmania (M. Baker pers. comm., Mar 2006). It is considered to be a significant weed in the British Isles and Ireland and is also naturalised in New Zealand, Belgium and France (Sykes in Webb et al. 1988, Cronk & Fuller 1995). This species spreads by seed and vegetatively by layering, and cut stems are reported to resprout (Cronk & Fuller 1995). *Rhododendron ponticum* produces an andromedo-toxin and the leaves are unpalatable to herbivores (Cronk & Fuller 1995).

FABACEAE (CAESALPINIOIDEAE)

Senna multijuga (Rich.) H.S.Irwin & Barneby

November Shower

Description: Tree to 40 m high. See Barneby in Steyermark et al. (1998), Lorenzi (1992) and Martius (1870).

Region of Origin: Native of South America, occurring from Colombia to Peru, Bolivia and Brazil.

New South Wales Distribution / Habitats: North Coast. At Bellingen, this species is most common in a wide unmanaged strip between a road and a pine plantation, but it is also naturalised alongside roads elsewhere in Bellingen and at Thora.

First Record: Alongside Kalang Road on southern edge of Bellingen, *J.R. Hosking 2271*, 14 Mar 2003 (AD, CANB, MEL, NE, NSW).

Notes: Many thousands of trees in native forest, a pine plantation and disturbed areas near Bellingen Hospital, some as tall as mature pines in the pine plantation. Collections of flowering plants were sent as herbarium specimens to NSW in 1965 and records of plantings in the Bellingen Hospital grounds show that this species was self-sown in the area in 1975. Plants are spread by movement of seed. The species is an attractive ornamental and is grown in many areas as a result. This species is not recorded as naturalised elsewhere in Australia. The only other known record of this species becoming a problem is from Puerto Rico, where it is a garden escape (Liogier 2000). It has also been recorded as naturalised in Hawaii, continental North America, West Indies and the Old World tropics (Wagner & Herbst 1999, Barneby in Steyermark et al. 1998).

FABACEAE (FABOIDEAE)

Desmanthus virgatus L.

Desmanthus

Description: Erect to sprawling shrub to 2 m high. See Cowan in Orchard (1998a).

Region of Origin: Native to the Americas, from Texas to Argentina and Uruguay.

New South Wales Distribution / Habitats: North Western Plains. Found in pasture in woodland where it was growing with shrubs and small trees of *Vachellia farnesiana*, *Capparis mitchellii*, *Citrus glauca*, *Geijera parviflora* and *Ventilago viminalis* with an understorey where the most common species are *Sclerolaena birchii*, *Chloris virgata*, *Setaria parviflora* and *Solanum esuriale*.

First Record: Site bsw041 located 30 km N (351 degrees) of Pallamallawa, on freehold property "Morven Downs", E of Gil Gil Creek, *B.S. Waanan 95*, May 2002 (NSW).

Notes: Spread by seed. A weedy species in disturbed coastal habitats from the Darwin region to Queensland (Dunlop *et al.* 1995). It is used as a pasture species and considered to be a long-lived perennial that provides high-quality stockfeed and withstands heavy grazing (Geesink *et al.* in Wagner *et al.* 1999, Crocker and Moylan 2004, Armstrong et al. 1997). This species is also naturalised in Florida, Chile, South Africa, Mauritius and on Pacific islands (Holm *et al.* 1979, Wunderlin and Hansen 2004, Arroyo *et al.* in Mooney and Hobbs 2000, Germishuizen in Arnold and de Wet 1993, Smith 1985). For more information on this species see Dunlop *et al.* (1995).

Lathyrus tingitanus L.

Tangier Pea

Description: Climbing herb to 3 m high on supporting vegetation. See Weber in Jessop & Toelken (1986), Jeanes in Walsh & Entwisle (1996), Hussey et al. (1997) and Muyt (2001).

Region of Origin: Native of Africa (northern Algeria, Morocco), Europe (Spain, Portugal), Mediterranean islands (Sardinia), Azores, Madeira and the Canary Islands.

New South Wales Distribution / Habitats: Central Tablelands, Central Coast, South Coast. Recorded from shrubby *Eucalyptus* spp. woodland on granite-derived sandy soil in the Central Tablelands.

First Record: Casula near Liverpool, *E. McBarron 14499*, 21 Oct 1967 (NSW).

Additional Records: Casula near Liverpool, *E. McBarron 14561*, 4 Nov 1967 (NSW); Eden, *C. Evans s.n.*, 24 Oct 1978 (NSW), 1.7 km along Jenolan Caves Road, south of Wicketty War Road, near Hampton, *J.R. Hosking 2416*, 10 Dec 2003 (CANB, MEL, NE, NSW).

Notes: This species has been previously confused with *Lathyrus latifolius* in N.S.W. Field notes by *McBarron 14499 & 14561* describe the species as bushy herbs to 5 ft wide and 3 ft high, growing as tangled masses along railway line and over recent earthworks. Field notes of *Evans s.n.* list *L. tingitanus* as growing on roadsides in several locations in the Eden district. *Hosking 2416* records the species as growing over more than 1 km of roadside and on a steep east facing slope in the collection area. This species is also recorded as naturalised in all Australian states except the Northern Territory. Hussey et al. (1997) indicate that the species is increasing rapidly on roadsides and other disturbed ground in the Darling Range near Perth. It is likely to become a more widespread environmental weed in N.S.W. *Lathyrus tingitanus* is widely naturalised and locally common to abundant in New Zealand and is naturalised in the western USA (Webb in Webb et al. 1988, Isely in Hickman 1993). For more information on this species see Muyt (2001).

Maackia amurensis Rupr. & Maxim.

Description: Deciduous tree to 14 m high. See Makino (1964), Ohwi (1965), Iwatsuki et al. (2001) and Hooker (1881, as *Cladrastis amurensis*).

Region of Origin: Native of China, Japan, Korea and far eastern Russia.

New South Wales Distribution / Habitats: Central Tablelands. Only known from a disturbed area between a garden and wet sclerophyll forest where it is growing on basalt-derived red-brown clay loam soil.

First Record: 'Joalah', Skyline Road, Mt Tomah, *J.R. Hosking 2292, C.H. Barker & N.W. Rodd*, 27 Mar 2003 (CANB, MEL, NE, NSW).

Notes: This species is spread by movement of seed, with naturalised plants appearing to be downwind from the parent tree. In the collection area there were over 20 plants arising from a garden tree growing nearby. Four of these 20 plants had pods. This species is not known to be naturalised elsewhere in Australia or overseas.

FABACEAE (MIMOSOIDEAE)

Inga edulis Mart.

Ice Cream Bean

Description: Tree to 30 m high. See Cárdenas & Berry in Steyermark et al. (2001).

Region of Origin: Native of South America (Bolivia and Brazil to Colombia, Suriname and Venezuela).

New South Wales Distribution / Habitats: North Coast. Only known from overgrown area of a garden where a tree of this species was removed. Growing on basalt-derived red clay loam soil.

First Record: 6 Dianella Road off Shelly Beach Road, Port Macquarie, *J.R. Hosking 2194, R. Pullen, D. Smith & G. Taylor*, 25 Feb 2002 (CANB, MEL, NE, NSW).

Additional Record: Woolgoolga Creek, near Woolgoolga, *J. Berrigan s.n.*, 7 Oct 2003 (NSW).

Notes: The species is spread by seed. In the Port Macquarie collection area, there were over 30 seedlings emerging in long grass around a stump of this species. Conditions were particularly moist over the previous winter and this appears to have led to germination. At the Woolgoolga site, there was a single naturalised juvenile plant 1 m high. Although no plants have reached reproductive age at either site, the number of young plants indicate that this species has the potential to naturalise on the north coast of N.S.W. *Inga edulis* is cultivated for the edible pulp surrounding the seeds (Cárdenas & Berry in Steyermark et al. 2001). This species appears to be naturalising in the Cairns – Daintree region of far north Queensland (B. Waterhouse pers. comm., Oct 2004, *Jago 6275* – BRI) and is naturalised in low numbers in the Galapagos Islands (Tye in Groves et al. 2001).

HIPPOCASTANACEAE

Aesculus indica Colebr.

Indian Horse Chestnut

Description: Tree to 15 m high. See Hooker (1859) and Spencer (2002).

Region of Origin: Native of eastern Afghanistan, India (Himachal Pradesh, Jammu, Kashmir, northern Uttar Pradesh), Nepal and northern Pakistan.

New South Wales Distribution / Habitats: Central Tablelands. Naturalising on basalt-derived red-brown clay-loam soils in warm temperate rainforest dominated by *Doryphora sassafras*, *Dicksonia antartica*, *Acmena smithii*, *Hymenanthera dentata* and *Acacia melanoxylon*.

First Record: Slope below garden, 'Lindfield Park', Mt Irvine, *J.R. Hosking 2277 & C.H. Barker*, 24 Mar 2003 (CANB, MEL, NE, NSW).

Notes: There are many hundreds of plants growing over an area 18 m x 10 m down a steep slope from planted trees. These trees were up to 5 m high and still non-reproductive at the time of collection. The spread of this species is by movement of fruit. This species is not recorded as naturalised in other states. Occasional adventive saplings of *A. indica* have been collected near Poverty Bay in New Zealand and are believed to have resulted from seeds washed down into a forest from cultivated plants in an arboretum above this area (Webb et al. 1995).

LAMIACEAE

Ajuga reptans L.

Common Bugle, Bugle

Description: Stoloniferous herb to 25 cm high. See Sykes in Webb et al. 1988.

Region of Origin: Native of Europe, Asia (northern Turkey to northern Iran, Dagestan and Ciscaucasia) and northern Africa (northern Algeria, Tunisia).

New South Wales Distribution / Habitats: Central Tablelands. On damp areas in the upper Blue Mountains on sandstone-derived sandy soils.

First Record: Simpson Avenue road reserve, Blackheath, *C.H. Barker 1 & J.R. Hosking*, 25 Nov 2002 (CANB, MEL, NE, NSW).

Notes: In the collection area, plants grow as a groundcover over an area of about 7 m x 2 m. Naturalised plants are also known from Katoomba and Lyrebird Dell, South Leura. *Ajuga reptans* appears to be spreading by stolons from existing plantings and by movement of stem sections along watercourses. This species is naturalised and listed as 'weedy on roadsides and creeks' in Tasmania (Rozefelds et al. 1999). It is also naturalised in New Zealand, Canada and the USA (Sykes in Webb et al. 1988, Gleason & Cronquist 1991).

Glechoma hederacea L.

Ground Ivy

Description: Rhizomatous herb to 30 cm high. See Sykes in Webb et al. (1988), Roy et al. (1998), Uva et al. (1997) and Stubbendieck et al. (1995).

Region of Origin: Native of Europe and Asia.

New South Wales Distribution / Habitats: Northern Tablelands. Naturalised in disturbed grassy woodland.

First Record: New England National Park, 1.2 km WNW of Point Lookout, adjacent to fence surrounding Navigation Towers, *L.M. Copeland 2168*, 14 Nov 1999 (CANB, NE, NSW).

Notes: Field notes of *Copeland 2168* record this species as an occasional plant in the collection area. This species is spread by seed and locally by rhizomes. In north eastern USA it is commonly found in damp shady areas but will grow in full sunlight (Uva et al. 1997). The species is listed as possibly naturalised in the Southern Lofty region of South Australia (Barker et al. 2005) and in the Mt Glorious area, west of Brisbane, in Queensland (*Phillips 803, 916* – BRI). It is recorded as naturalised on the north and south islands of New Zealand and in North America (Sykes in Webb et al. 1988, Roy et al. 1998, Scoggan 1979, Alex & Switzer 1976, Uva et al. 1997). In Canada and the USA it is a weed of turfgrass, gardens, roadsides, waste areas, pasture, open woods and perennial fruit crops (Scoggan 1979, Alex & Switzer 1976, Uva et al. 1997).

Lamium galeobdolon (L.) L.

Aluminium Plant, Yellow Archangel

Description: Trailing perennial herb to 25 (rarely to 40) cm high. See Conn in Walsh & Entwisle (1999).

Region of Origin: Native of Europe and Asia (Turkey, Azerbaijan, Georgia, northern Iran).

New South Wales Distribution / Habitats: Central Tablelands. Wet sclerophyll forest.

First Record: Below Wells Street, Catalina Park, Katoomba, *C.H. Barker 14 & J.R. Hosking*, 26 Nov 2003 (CANB, MEL, NE, NSW).

Notes: Commonly planted as an ornamental and appears to spread via trailing stems that root from nodes, and via seed. Naturalised in a number of locations around Katoomba and Wentworth Falls, and in the Dandenong Ranges (Victoria). The first naturalised specimen (*Clarke 2291 & Albrecht* – MEL) was collected near Yarragon in south eastern Victoria in May 1993. The species is also naturalised in Tasmania (HO specimen). *Lamium galeobdolon* is naturalised in New Zealand and the USA (Sykes in Webb et al. 1988, as *Galeobdolon luteum* Huds., USDA, NRCS 2006, as *Lamiastrum galeobdolon* (L.) Ehrend. & Polatschek).

Physostegia virginiana (L.) Benth.

Dragonhead, Obedient Plant

Description: Rhizomatous herb with erect stems to 95 cm high. See Steyermark (1963).

Region of Origin: Native of Canada, USA and northern Mexico.

New South Wales Distribution / Habitats: North Coast and Central Coast. Naturalised on roadsides in a number of areas.

First Record: Lane Cove Road, about 0.3 km from junction with Mona Vale Road, Church Point, *J.T. Waterhouse UNSW 3480*, 14 Mar 1975 (NSW).

Additional Records: Maitland, East, *B. Auld 120037*, 11 Mar 1982 (NSW); roadside drain alongside Waukivory Road, about 50 m from The Bucketts Way East, Gloucester, *J.R. Hosking 2201 & M.W. Tull*, 1 Mar 2002 (CANB, MEL, NE, NSW).

Notes: An attractive ornamental, naturalised on roadsides at Church Point in 1975, in East Maitland in 1982 and growing over 70 m of a roadside ditch alongside pasture at Gloucester in 2002. The species appears to spread via rhizomes and possibly by seed. This species is not recorded as naturalised in other states. The species is considered to have naturalised in Florida, but is considered native elsewhere in the USA (USDA, NRCS 2006, Wunderlin & Hansen 2004).

Plectranthus ecklonii Benth.

Blue Spurflower

Description: Shrub to 3 m high. See Conn in Walsh & Entwisle (1999).

Region of Origin: Native of South Africa.

New South Wales Distribution / Habitats: Central Coast. Recorded from *Syncarpia glomulifera* and *Allocasuarina torulosa* forest mostly on edge where it is growing with *Plectranthus verticillatus*, *Elurharta erecta* and *Sida rhombifolia*.

First Record: Alongside Maraket Avenue, Blaxland, *J.R. Hosking 2215 & C.H. Barker*, 24 Apr 2002 (CANB, MEL, NE, NSW).

Notes: In the collection area the species was growing in four clumps, the largest occupying an area of about 3 m x 2 m and one clump was about 50 m down-slope from the roadway and in native forest. It appears to have originated from dumped garden waste, with plants present in a garden across the road at the time of collection. *Plectranthus ecklonii* appears to spread vegetatively and possibly by seed. This species is recorded as naturalised in *Eucalyptus regnans* tall open-forest in Victoria (Conn in Walsh & Entwisle 1999) and in New Zealand (Sykes in Webb et al. 1988).

MALVACEAE (MALVOIDEAE)

Abutilon pictum (Gillies ex Hook. & Arn.) Walp. [syn. *Abutilon striatum* Dicks. ex Lindl., *Sida picta* Gill.]

Chinese Lantern

Description: Shrub to 5.5 m high. See Standley & Steyermark (1949), Spencer (1997) and Hooker (1840).

Region of Origin: Native of South America occurring in Ecuador, Peru, Brazil, northern Argentina, Paraguay and Uruguay.

New South Wales Distribution / Habitats: Central Coast. Naturalised near plantings of this species.

First Record: Creekline north of Burfitt Parade, north west of Glenbrook Railway Station platform, Glenbrook, *C.H. Barker 11*, 17 Sep 2003 (CANB, MEL, NE, NSW).

Notes: At Glenbrook, this species was spreading by layering of stems that root where in contact with the ground. In this area, there were about 400 erect stems of this *Abutilon* growing along an urban creekline over an area of about 6 m x 40 m. Although we regard *A. striatum* to be a synonym of *A. pictum*, there is some debate as to whether these two should be considered separate species (Standley and Steyermark 1949). If these two taxa were to be regarded as distinct species, then the naturalised taxon occurring at Glenbrook represents *A. striatum* (sensu stricto). *Abutilon pictum* is listed as naturalised in Victoria (MEL specimen) and *A. striatum* is listed as naturalised in Guatemala (Standley and Steyermark 1949).

OXALIDACEAE

Oxalis vallicola (Rose) R. Knuth

Description: Herb with inflorescence to 30 cm high. See Sykes in Webb et al. (1988).

Region of Origin: Native of Mexico.

New South Wales Distribution / Habitats: Central Tablelands. This species appears to be naturalised where garden waste has been discarded.

First Record: Edge of park behind vacant house block off Selby Street, Katoomba, *C.H. Barker 20 & J.R. Hosking*, 3 Dec 2003 (CANB, MEL, NE, NSW).

Additional Records: Albury (weed in garden), *E.J. McBarron 4282*, 17 Dec 1949 (NSW); Albury (in home garden), *H.J. Milvain s.n.*, 19 Mar 1974 (NSW).

Notes: Grows in dense clumps, with plants producing large numbers of bulbils within a brown tunic around the main bulb. This species appears to be spreading by bulbils and possibly also by seed. At Katoomba, the species is growing over an area of about a third of a vacant house block and into the edge of a neighbouring park. There are earlier records from gardens in Albury and the species is likely to be naturalised in and around Albury. This species is naturalised in the Dandenong Ranges, Victoria (Ross & Walsh 2003). In New Zealand, the species is recorded from 'waste and cultivated ground' and is listed as widespread (Sykes in Webb et al. 1988). *Oxalis vallicola* is regarded as a synonym of *Oxalis latifolia* in North America (Denton 1973), but that species has bulbs on stolons, whereas *O. vallicola* does not.

PITTOSPORACEAE

Pittosporum eugenioides A.Cunn.

Lemonwood, Tarata

Description: Tree to 15 m high. See Allan (1961) and Poole & Adams (1990).

Region of Origin: Native of the north and south islands of New Zealand.

New South Wales Distribution / Habitats: Central Tablelands. Naturalised in the upper Blue Mountains near plantings of this species.

First Record: Gully between current ends of Thirroul Street, Blackheath, *J.R. Hosking 2294 & C.H. Barker*, 27 Mar 2003 (CANB, MEL, NE, NSW).

Notes: Collected in 2003 from Blackheath where it is growing in disturbed dry sclerophyll forest with many exotic species on sandstone-derived sandy soils. Four plants in the collection area, with more than 20 plants nearby. The species has bird-dispersed seed. A variegated form of the species is commonly used as a hedge plant but naturalised plants are mostly not variegated. *Pittosporum eugenioides* is naturalised in Victoria with the first naturalised specimen (*Clarke 2289 & Albrecht* – CANB, MEL) collected near Yarragon in May 1993. The species is not recorded as naturalised in other Australian states.

Pittosporum ralphii Kirk

Karo, Ralph's Kohuhu

Description: Shrub to 7 m high. See Allan (1961) and Poole & Adams (1990).

Region of Origin: Native of the north island of New Zealand.

New South Wales Distribution / Habitats: Central Tablelands. Recorded from *Eucalyptus piperita* and *E. oreades* wet sclerophyll forest invaded by exotics such as *Cotoneaster franchetii*, *Hedera helix* and this species.

First Record: Alongside Cliff Drive between Katoomba Falls Kiosk and Kedumba River, Katoomba, *J.R. Hosking 2242 & C.H. Barker*, 25 Nov 2002 (CANB, MEL, NE, NSW).

Notes: Over 50 naturalised plants scattered near the 2002 collection point and other plants scattered elsewhere in this catchment. Subsequent visits to the area revealed that the species is more widespread and is naturalised over about four square kilometres on the southern side of Katoomba. The species is grown as an ornamental. It has bird-dispersed seed and appears likely to become a common understorey species in this area. Although not recorded as naturalised elsewhere in Australia, *P. ralphii* is naturalised outside its native range in New Zealand (P. Heenan pers. comm., Mar 2003).

Pittosporum tenuifolium Gaertn.

Kohuhu

Description: Shrub or small tree to 10 m high. See Allan (1961) and Poole & Adams (1990).

Region of Origin: Native of the north and south islands of New Zealand.

New South Wales Distribution / Habitats: Central Tablelands. Recorded from disturbed margin of *Eucalyptus piperita* shrubby woodland where it is growing with *Banksia spinulosa*, *Leptospermum trinervium*, *Hakea laevipes* and *Lambertia formosa*.

First Record: Alongside and below firebreak behind houses on Jersey Avenue, Leura Park, Leura, *C.H. Barker 23 & J.R. Hosking*, 3 Dec 2003 (CANB, MEL, NE, NSW).

Notes: Twenty-one shrubs were counted up to 20 m into native vegetation in the collection area. Only one shrub was in fruit; another large naturalised non-fruiting shrub was seen in native vegetation near Echo Point, Katoomba. This species occurs as scattered young shrubs elsewhere in upper Blue Mountains. The species has bird-dispersed seed. *Pittosporum tenuifolium* is naturalised in Victoria with the first naturalised specimen (*Jobson 393* – A, MEL, NSW) collected 21 km N of Cressy in 1988 and in Tasmania where the first naturalised specimen (*Cayzer 894* – CANB) was collected from Port Arthur in 2000. The species is also naturalised in California (McClintock in Hickman 1993).

PRIMULACEAE

Lysimachia fortunei Maxim.

Description: Erect to decumbent herb to 70 cm high. See Ohwi (1965) and DeVol in Li et al. (1978a).

Region of Origin: Native of Vietnam, China, Korea and Japan.

New South Wales Distribution / Habitats: Northern Tablelands. Recorded from a swamp where it was growing in a herbfield with *Carex gaudichandii*, *Geum urbanum*, *Juncus* sp. and *Lysimachia* sp. on basalt-derived black peaty loam soils.

First Record: Werrikimbe National Park, SW side of Racecourse Swamp, 100 m E of track crossing of Hastings River, *L.M. Copeland 3557, I.R. Telford & J. Hodgon*, 13 Feb 2002 (BRI, CANB, MEL, NE, NSW).

Notes: The species was abundant in the collection area but it is not clear how it reached this area (I. Telford pers. comm., May 2003). This species is spread by rhizomes, stolons and seed. It is not recorded as naturalised in other Australian states. In Japan the species is considered to be a common weed (Holm et al. 1979).

PROTEACEAE

Athertonia diversifolia (C.T.White) L.A.S.Johnson & B.G.Briggs

Atherton Oak

Description: Tree to 30 m high. See Weston in Orchard (1995).

Region of Origin: Native of the Atherton Tablelands in Queensland, Australia.

New South Wales Distribution / Habitats: North Coast. Recorded from alongside existing plantings of this species in a high rainfall area on well-drained structured red earth soils.

First Record: Naturalising in Bellingen Hospital grounds, Bellingen, *J.R. Hosking 2274 & I. Turnbull*, 14 Mar 2003 (CANB, MEL, NE, NSW).

Notes: Naturalising in the collection area where there were two juvenile plants 1 m and 2 m high. The source trees were planted in the area in 1965 from material collected by J. King from Atherton (unpublished document on plantings in Bellingen Hospital grounds). This species is spread by seed. It has not previously been recorded as naturalising outside its natural range.

RANUNCULACEAE

Aquilegia vulgaris L.

Columbine, Granny Bonnets

Description: Herb to 1.6 m high. See Walsh in Walsh & Entwisle (1996).

Region of Origin: Native to Europe and northern Africa (Algeria, Morocco).

New South Wales Distribution / Habitats: Central Tablelands. Recorded from wet sclerophyll forest.

First Record: Below Wells Street, Catalina Park, Katoomba, *C.H. Barker 15*, 21 Nov 2003 (CANB, MEL, NE, NSW).

Notes: There were only four plants seen in the collection area but the species is also scattered elsewhere in disturbed areas at Katoomba. It spreads by seed. This species is also naturalised in Victoria (first naturalised specimen (*Rogers s.n.* – MEL) from Boundary Creek near the Snowy River, November 1961). It also appears to be naturalising in Tasmania, although most collections are near houses or where garden waste has been dumped (A. Buchanan pers. comm., Mar 2004). The species has not been recorded as naturalised in other Australian states. It is naturalised in the USA, Canada and outside its native range in Europe (Gleason & Cronquist 1991, Cullen & Heywood in Tutin et al. 1964).

Clematis montana DC.

Description: Climber to 4 m high on supporting vegetation. See Garnock-Jones in Webb et al. (1988).

Region of Origin: Native of Afghanistan, India, Bhutan and China.

New South Wales Distribution / Habitats: Central Tablelands. Recorded from *Eucalyptus piperita*, *E. sieberi*, *Banksia cunninghamii* subsp. *cunninghamii* and *Pittosporum undulatum* forest on sandstone-derived sandy soils.

First Record: Gordon Falls Reserve, alongside toilet block, over road from 13 Lone Pine Avenue, Leura, *J.R. Hosking 2245*, 26 Nov 2002 (AD, CANB, MEL, NE, NSW).

Notes: Known from several localities in the upper Blue Mountains. In March 2003, in Gordon Falls Reserve, there were a number of new plants growing in native forest near the toilet block. It appears to have reached this area via wind-dispersed seed as the species is visible in a garden across the road from naturalised plants. *Clematis montana* has not been recorded as naturalised in any other Australian state. It is naturalised in New Zealand (Garnock-Jones in Webb et al. 1988).

ROSACEAE (AMYGDALOIDEAE)

Prunus campanulata Maxim. [syn. *Prunus cerasoides* D.Don var. *campanulata* (Maxim.) Koidz., *Cerasus campanulata* (Maxim.) A.N.Vassiljeva]

Taiwan Cherry

Description: Shrub or small tree to 8 m high. See Sykes & Given in Webb et al. (1988), Su in Li et al. (1977) and Sealy (1939).



Fig. 3. *Pittosporum ralphii* is only known to be naturalised in Australia in higher areas of the Blue Mountains.

Region of Origin: Native of China (Fujian, Guangdong, Guangxi, Zhejiang), Japan (Ryukyu Islands) and Taiwan.

New South Wales Distribution / Habitats: Central Coast. In a gully forest with *Ligustrum sinense*, *Lantana camara*, *Lomandra* sp., *Morinda jasminoides*, *Ochna serrulata*, *Allocasuarina torulosa*, *Cinnamomum camphora* and *Corymbia gummifera*.

First Record: Gully N of northern part of Hume Road, Lapstone, *J.R. Hosking 2332 & C.H. Barker*, 21 Aug 2003 (AD, CANB, MEL, NE, NSW).

Additional Record: Gully N of northern part of Hume Road, Lapstone, *J.R. Hosking 2411*, 6 Dec 2003 (AD, CANB, MEL, NE, NSW).

Notes: More than ten naturalised flowering and fruiting trees were scattered over an area of about 100 m of gully and a single naturalised plant was seen in an adjacent gully north of the collection site. A planted tree was also noted on the nature strip of Darwin Drive (immediately to the north of the collection site). This species appears to be spreading via bird-dispersed seed. *Prunus campanulata* has not been recorded as naturalised in any other Australian state. It is naturalised in New Zealand (Sykes & Given in Webb et al. 1988).

ROSACEAE (MALACOIDEAE)

Cotoneaster simonsii Baker

Himalayan Cotoneaster

Description: Shrub to 2 m high. See Symon in Jessop & Toelken (1986).

Region of Origin: Native of India (Sikkim), Bhutan and Nepal.

New South Wales Distribution / Habitats: Central Tablelands. Scattered in disturbed areas throughout the upper Blue Mountains. Recorded from edge of *Pinus radiata* plantation with *Cotoneaster franchetii*, *Ilex aquifolium*, *Prunus laurocerasus* and *Pteridium esculentum*.

First Record: Alongside Prince Edward Street, 45 m N of junction with Belvedere Avenue, Blackheath, *J.R. Hosking 2252 & P.T. Gorham*, 28 Nov 2002 (CANB, MEL, NE, NSW, SA).

Additional Records: Alongside Prince Edward Street, 45 m N of junction with Belvedere Avenue, Blackheath, *J.R. Hosking 2280*, 25 Mar 2003 (AD, CANB, MEL, NE, NSW); Alongside Bureau Park, Katoomba, *J.R. Hosking 2436 & C.H. Barker*, 7 Feb 2004 (AD, CANB, MEL, NE, NSW).

Notes: *Hosking 2280* records four naturalised mature shrubs in the collection area and five fruiting naturalised shrubs on neighbouring vacant land. The same label mentions that other naturalised plants of this species were seen elsewhere in Blackheath (many plants) and Katoomba (a few plants). Field information provided by *Hosking 2436 & Barker* records about 20 plants in the collection area. This species is often growing with *C. franchetii*, a species that is much more common and likely to be confused with *C. simonsii*. *Cotoneaster simonsii* spreads via bird-dispersed seed. This *Cotoneaster* is recorded as naturalised in Victoria, Tasmania and South Australia (Ross & Walsh 2003, Baker 2005, Symon in Jessop & Toelken 1986). It is also naturalised on the north and south islands of New Zealand (where it is locally abundant), throughout the British Isles and in France, Ireland, Norway and the USA (Sykes & Given in Webb et al. 1988, Clement & Foster 1994, Browicz in Tutin et al. 1968, USDA, NRCS 2006).

Cotoneaster* x *watereri Exell group

Cotoneaster

Description: Only known naturalised shrub was 3.5 m high. See Stace (1997).

Region of Origin: Hybrid developed in cultivation.

New South Wales Distribution / Habitats: Central Tablelands. Recorded from edge of *Eucalyptus piperita*, *E. sieberi*, *Banksia cunninghamii* subsp. *cunninghamii* and *Pittosporum undulatum* dry sclerophyll forest.

First Record: Gordon Falls Reserve, c. 4 m from road edge, over road from 9 Lone Pine Avenue, Leura, *J.R. Hosking 2246*, 26 Nov 2002 (CANB, MEL, NE, NSW, SA).

Additional Record: Gordon Falls Reserve, c. 4 m from road edge, over road from 9 Lone Pine Avenue, Leura, *J.R. Hosking 2275*, 24 Mar 2003 (AD, CANB, MEL, NE, NSW).

Notes: *Hosking 2275* states the plant is unlikely to have been planted in this area, and cultivated plants are present in a garden immediately opposite the collection site. Dispersal to this site is likely to have been via dumped garden refuse or bird-dispersed seed. Another plant of this group has been identified from the Dandenong Ranges in Victoria (Ross & Walsh 2003). The *C.* x *watereri* group is reported to be a complex of hybrids between *C. frigidus* Wall. ex Lindl., *C. henryanus* (C.K.Schneid.) Rehder & E.H.Wilson, *C. salicifolius* Franch. and possibly other species (Clement & Foster 1994). *Cotoneaster* x *watereri* is naturalised in many parts of Britain and Ireland (Stace 1997).

ROSACEAE (ROSOIDEAE)

Potentilla vesca (L.) Scop. [syn. *Fragaria vesca* L.]

Alpine Strawberry, Woodland Strawberry

Description: Herb to 30 cm high. See Given & Webb in Webb et al. (1988, as *F. vesca*) and Ross-Craig (1955).

Region of Origin: Native of northern hemisphere.

New South Wales Distribution / Habitats: Central Tablelands. Growing below *Pinus radiata*, *Eucalyptus radiata* and *E. piperita* with native and exotic shrubs and herbs.

First Record: Bushland alongside southern end of Caseade Street, Katoomba, *C.H. Barker 28*, 26 Nov 2003 (CANB, MEL, NE, NSW).

Notes: The generic name *Potentilla* is here adopted in preference to *Fragaria* for reasons given in Mabberley (2002). *Potentilla vesca* has only been collected from the above location where it was abundant over an area of 3 m x 2.5 m and scattered elsewhere at this location. It has also been observed as a roadside weed in three other locations in Katoomba. This species appears to be spreading via rhizomes and stolons and possibly by seed. *Potentilla vesca* is not recorded as naturalised in other Australian states. It is recorded as naturalised on the north and south islands of New Zealand and in Hawaii (Given & Webb in Webb et al. 1988, Wagner et al. 1999).

Rosa luciae Franch. & Rochebr. ex Crép. **hybrids** [syn. *Rosa wichuraiana* Crép. or *Rosa wichurana* Crép. hybrids]

Rambler Rose

Description: Scrambling shrub to 6 m high on supporting vegetation. See as *R. wichuriana* in Sykes & Given in Webb et al. (1988) and Phillips & Rix (1988).

Region of Origin: Native to China, Korea and Japan.

New South Wales Distribution / Habitats: Central Coast, Central Tablelands and North Western Slopes. Spreading alongside areas where the species was planted or where it has been discarded as garden waste.

First Record: Harbord, Oliver Street, near intersection with Pittwater Road, *M.J. Taylor 156*, 1 Dec 1983 ('Dorothy Perkins' group, flowers double – NSW).

Additional Records: Alongside road to Oxley Lookout, Oxley Park, Tamworth, *J.R. Hosking 618 & R.H. Holtkamp*, 19 Nov 1992 (single flower – CANB, MEL, NE, NSW); Alongside road to Oxley Lookout, Oxley Park, Tamworth, *J.R. Hosking 726*, 31 Mar 1993 (single flower – CANB, MEL, NE, NSW); About 200 m west of Olympic Pool and north of Farnells Road, Katoomba, *J.R. Hosking 2244*, 26 Nov 2002 ('Dorothy Perkins' group, flowers double – AD, CANB, MEL, NE, NSW).

Notes: This taxon appears to be spreading from existing plants and from where garden waste has been dumped. It is a common roadside weed in the mid to upper Blue Mountains. Both double and single flowered forms are naturalised. *Rosa luciae* is also naturalised in Victoria (Ross & Walsh 2003) and on the north and south islands of New Zealand (Sykes & Given in Webb et al. 1988) and in the USA (USDA, NRCS 2006).

Rubus rugosus Sm. [syn. *R. rugosus* var. *thwaitesii* Focke]

Keriberry

Description: Scrambling shrub. See Webb & Given in Webb et al. (1988). The species has previously been referred to as *R. rugosus* var. *thwaitesii*.

Region of Origin: Native of Asia (India, Nepal and Sri Lanka to Malay Peninsula and Vietnam).

New South Wales Distribution / Habitats: North Coast. Recorded from alongside house at Comboyne. Likely to grow below perching sites for birds near areas where plants have been cultivated.

First Record: Property of Hartmutt Kiehn, 'Yallaban', Comboyne, *J.R. Hosking 2196, H. Kiehn, T. Schmitzer, P. Leddy, D. Smith & G. Taylor*, 26 February 2002 (AD, CANB, MEL, NE, NSW).

Notes: According to Kiehn (pers. comm., Feb 2002), cultivated plants were removed from his property in 1999, but naturalised plants are still being found. The species was promoted as a source of edible fruit in the late 1900s and is likely to be naturalised in areas near original plantings as the species is attractive to birds and seed is animal-dispersed. *Rubus rugosus* is recorded as naturalised in Victoria (first naturalised specimen (*Stajsic s.n., Sago & Crosbie* – BRI, CANB, MEL) collected in Selby Conservation Park in May 1999). The species is also recorded as naturalised in Western Australia and Tasmania (PERTH and HO specimens).

RUBIACEAE

Coprosma* x *cunninghamii Hook.f. (*Coprosma propinqua* A.Cunn. x *Coprosma robusta* Raoul)

Description: Shrub to 7 m high. See Taylor (1961).

Region of Origin: A natural hybrid found widely in New Zealand.

New South Wales Distribution / Habitats: Central Tablelands. Mount Tomah, recorded from tall open forest of *Eucalyptus fastigata, E. blaxlandii, Angophora costata* and *Hedycarya angustifolia* with a shrub and grass understorey.

First Record: Bells Line of Road, alongside Mt Tomah Botanic Gardens, Mt Tomah, *C.H. Barker 12*, 30 Sep 2003 (AD, CANB, MEL, NE, NSW).

Additional Record: Bells Line of Road, alongside Mt Tomah Botanic Gardens, Mt Tomah, *C.H. Barker 29 & J.R. Hosking*, 5 Dec 2003 (CANB, MEL, NE, NSW).

Notes: Only known in the wild in Australia from a single naturalised plant, the parents of this hybrid being grown in Mt Tomah Botanic Gardens and probably the source of this naturalised plant. The single plant was producing large amounts of fruit at the time of collection and, as with other *Coprosma* species, this hybrid is likely to be spread by bird-dispersed seed. This hybrid is not recorded as naturalised in other Australian states. According to Poole and Adams (1990), *C. propinqua* often hybridises with *C. robusta* and can form extensive hybrid swarms.

Coprosma robusta Raoul

Karamu

Description: Shrub or small tree to 6 m high. See Jeanes in Walsh & Entwisle (1999), Allan (1961) and Poole & Adams (1990).

Region of Origin: Native of the north and south islands of New Zealand.

New South Wales Distribution / Habitats: Central Tablelands. Mount Tomah, growing in tall open forest on basalt derived soils.

First Record: On north-western side of Bells Line of Road, near Mount Tomah Botanic Gardens, Mt Tomah, *J.R. Hosking 2278 & C.H. Barker*, 30 Sep 2003 (CANB, MEL, NE, NSW).

Notes: This species is known from locations around Mount Tomah Botanic Gardens, where the species is in cultivation. Spread is via bird-dispersed seed. *Coprosma robusta* is recorded as naturalised in Victoria and Tasmania (Jeanes in Walsh & Entwisle 1999, Rozefelds et al. 1999). In Victoria, this species is becoming increasingly common in the Dandenong Ranges. The first collection of this species (*Opie s.n. & Wellington* – MEL) was made in May 1977 from Doongalla Estate in Victoria and was probably collected from naturalised plants, although this was not stated by the collectors.

SAXIFRAGACEAE

Bergenia* x *schmidtii (Regel) Silva Tar.

Description: Herb to 65 cm high. According to Yeo (1961) this taxon is likely to be a hybrid between *B. crassifolia* (L.) Fritsch and *B. ciliata* (Haw.) Sternb.

Region of Origin: Species of horticultural origin.

New South Wales Distribution / Habitats: Central Coast and Central Tablelands. Growing downslope from waste disposal area.

First Record: About 100 m below South Lawson tip site at end of Ridge Street, South Lawson, *J.R. Hosking 2324 & C.H. Barker*, 20 Aug 2003 (NSW).

Notes: *Hosking 2324 & Barker* noted only a single plant. However, this hybrid is also naturalised elsewhere in the Blue Mountains, occurring in small groups. In these cases, it would seem to be growing from discarded garden waste or plant material washed down from existing plantings. This hybrid, or a similar unknown *Bergenia* sp., occurs at a cool creekside location in Carlingford, Sydney. *Bergenia* x *schmidtii* is naturalised in the British Isles (Clement & Forster 1994).

SOLANACEAE

Cestrum* x *cultum Francey

Description: Shrub to 2 m high. See Huxley (1992) and Francey (1935). This hybrid is regarded as a cross between *C. elegans* and *C. parqui* (Huxley 1992).

Region of Origin: Species of horticultural origin.

New South Wales Distribution / Habitats: Central Coast. Lapstone, recorded from a drainage reserve where growing with *Lantana camara*, *Jasminum polyanthum*, *Ageratina adenophora* and *Bougainvillea glabra*.

First Record: Drainage reserve above junction of Dawes Place and Hume Road, Lapstone, *J.R. Hosking 2329 & C.H. Barker*, 21 Aug 2003 (AD, CANB, MEL, NE, NSW).

Notes: There are two clumps present at the collection site, possibly originally planted, but apparently spreading by suckering. Plants do not appear to be forming seed.

ULMACEAE

Ulmus* x *hollandica Mill.

Dutch Elm

Description: Tree to 40 m high. See Webb in Webb et al. (1988) and Hewson in George (1989). This taxon is said to be a hybrid between *U. glabra* Hudson and *U. minor* Mill. or a triple hybrid between *U. glabra*, *U. minor* and *U. plottii* Druce (Stace 1997).

Region of Origin: Native of Europe and Asia.

New South Wales Distribution / Habitats: Southern and Central Tablelands. Only recorded as growing on a steep slope with *Eucalyptus macrorhyncha*, *E. goniocalyx*, *Exocarpos cupressiformis*, *Acacia dealbata* and *Rubus* sp. (thought to be *R. discolor*, a name misapplied to *R. anglocandicans*).

First Record: 'Lanyon' homestead, A.C.T., *J. Olsen 1380*, Jan 1973 (NSW).

Additional Record: 'The Rocks', property W of Bathurst, *L.R. Cole s.n.*, 26 Aug 2003 (NSW).

Notes: *Ulmus* x *hollandica* spreads by suckering and possibly by movement of root material. The *Flora of Australia* treatment (Hewson in George 1989) suggested that *U.* x *hollandica* was naturalised in N.S.W. but this was not accepted by Harden (1990) or Harden and Murray (2000) presumably as the plant was locally suckering, rather being truly naturalised by their definition. Field information provided by *Olsen 1380* (cited by Hewson) states that there was a 'Tree c. 6 m tall, surrounded by dense thicket of suckers.' At the Bathurst site, according to *Cole s.n.* there were 28 trees at varying stages of growth and plants were not growing close to any habitation, past or present.

Ulmus x *hollandica* is recorded as naturalised in Victoria, Tasmania and South Australia (Ross & Walsh 2003, Rozefelds et al. 1999, Barker et al. 2005). The record of this plant being naturalised in Queensland (Jessup in Henderson 2002) is erroneous, based on a cultivated specimen (G. Batianoff pers. comm., Nov 2005). There is an earlier undated collection (*Curtis s.n.* – HO) from Taroona, a suburb of Hobart, probably in the 1950s. This taxon is recorded as naturalised in New Zealand (Webb in Webb et al. 1988).

Name changes and additional notes for some species recognised as naturalised in 2000–2001 (Hosking et al. 2003)

A number of species listed in Hosking et al. (2003) have been found to be incorrectly identified, and are listed below under the correct name, with the name used in Hosking et al. (2003) listed under Notes. The species order follows that used previously i.e. Conifers and allies, Monocotyledons, Dicotyledons. Entries are reduced if the names are correct and only additional notes on weediness are provided.

Conifers and allies

PINACEAE

Pinus halepensis Mill. [*Pinus nigra* J.F.Arnold var. *corsicana* (Loudon) Hyl., *pro parte* Hill in Orchard (1998b) see notes below; *sensu* Hosking et al. (2003)]

Aleppo Pine

Description: Tree to 30 m high. See Sykes in Webb et al. (1988), Hill in Orchard (1998b) and Henderson (2001).

Region of Origin: Native of southern Europe, Mediterranean islands, western Asia and northern Africa.

NSW Distribution / Habitats: Southern Tablelands, South Western Slopes. Naturalised near planted trees.

First Record: Stirling Ridge, near top of slope, 100 m W of mosque [ACT], *M.J. Mulvaney ANU 30060*, 14 Jan 1986 (CANB).

Additional Records: Yass River, c. 1 km NE of Yass Post Office, *B.J. Lepschi 1062*, 29 Aug 1993 (CANB, NSW); Northern outskirts of Griffith – southern edge of Kalinda Rd, 2.2 km E of the intersection with Wyangan Avenue, *D.J. Mallinson 642*, 30 Aug 2002 (CANB); Native shrubby woodland above the Wagga Wagga Botanic Gardens, Wagga Wagga, *J.R. Hosking 2507*, 10 Sep 2004 (CANB, MEL, NE, NSW).

Notes: Hill in Orchard (1998b) and Hosking et al. (2003) incorrectly recorded the occurrence of *P. nigra* var. *corsicana* in N.S.W. on the basis of *Lepschi 1062*. *Pinus halepensis* had not previously been recorded as naturalised in N.S.W. Naturalised occurrences range from a few scattered plants at the Yass River site, to over 100 young trees at the Wagga Wagga site (including plants from 2 m high bearing female cones). No details of population size are recorded for the Mulvaney collection. Dispersal of *P. halepensis* is via wind-dispersed seed. This pine is naturalised in Victoria, South Australia and Western Australia (Hill in Orchard 1998b). *Pinus halepensis* is one of the five most invasive *Pinus* species according to Rejmánek and Richardson (1996). *Pinus halepensis* is also naturalised in New Zealand, South Africa and Pakistan (Sykes in Webb et al. 1988, Henderson 2001). In Israel this pine is native to some areas but it has been widely planted for reafforestation and is now invading native vegetation alongside plantations (Lavi et al. 2005).

Dicotyledons

CACTACEAE

Cylindropuntia kleiniae (DC.) F.M.Knuth [*Cylindropuntia arbuscula* (Engelm. & J.M.Bigelow) F.M. Knuth *sensu* Hosking et al. (2003)]

Description: Shrub cactus to 2 m high. See Benson (1982, *Opuntia kleiniae* DC.) and Anderson (2001).

Region of Origin: Native of the USA (southern New Mexico, south western Texas) and Mexico (Chihuahua, Coahuila, Durango, Nuevo Leon).

NSW Distribution / Habitats: North Western Plains. Recorded from *Eucalyptus populnea* subsp. *bimbil* woodland.

First Record: Northern side of Grawin, *J.R. Hosking 1889*, 19 Sep 2000 (BRI, CANB, MEL, NE, NSW).

Additional Record: North western side of Lightning Ridge, *J.R. Hosking 2405 & W.A. Cherry*, 26 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD).

Notes: This species was incorrectly identified as *Cylindropuntia arbuscula* in Hosking et al. (2003). That identification was based on non-flowering material. However, once flowering material was available, this species was readily identified as *C. kleiniae*. These plants had pink flowers, whereas *C. arbuscula* has greenish yellow flowers. *Cylindropuntia kleiniae* is scattered elsewhere over the Lightning Ridge, Grawin and Glen Garry opal fields. It is damaged by the cochineal insect, *Dactylopius tomentosus*. This cactus is not known to be naturalised elsewhere in Australia.

Cylindropuntia leptocaulis (DC.) F.M.Knuth

Pencil Cactus

Additional Record: Northern side of Grawin, *J.R. Hosking 2399 & W.A. Cherry*, 25 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD); Alongside road parallel to railway line and on opposite side of railway line to Kamilaroi Highway, Curlewis, *J.R. Hosking 2427*, 1 Feb 2004 (CANB, MEL, NE, NSW).

Notes: The infestation near Curlewis is large, covering an area of about five hectares. In one location at Curlewis this cactus was the dominant species, covering an area of 90 m x 30 m.

Cylindropuntia rosea (DC.) Backeb. [*Cylindropuntia tunicata* (Lehm.) F.M.Knuth *sensu* Hosking et al. (2003).]

Hudson Pear

Description: Shrub cactus to 1.5 m high, although often mat-forming. See Anderson (2001).

Region of Origin: Native of Mexico.

NSW Distribution / Habitats: North Western Slopes, North Western Plains. Recorded from mixed *Eucalyptus* woodland.

First Record: Cumborah, growing behind abandoned garage, near turnoff to Lightning Ridge. *J.R. Hosking 1887, J.P., T.L. & G.R. Hosking*, 18 Sep 2000 (BRI, CANB, MEL, NE, NSW).

Additional Record: 1.1 km north east of Glen Garry, *J.R. Hosking 2395, W.A. Cherry & M.P. Goodwin*, 24 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD).

Notes: This species was incorrectly identified as *Cylindropuntia tunicata* in Hosking et al. (2003). Once flowering material was available, these plants were obviously *C. rosea*. This species has pink-purple flowers, whereas *C. tunicata* has pinkish-yellow flowers. *Cylindropuntia tunicata* was collected at Grawin in November 2003 and its presence is reported earlier in this paper. *Cylindropuntia rosea* has become established as a weed in the Lightning Ridge, Grawin and Glen Garry area. This cactus is not known to produce seeds but its segments are readily spread by floodwaters. Currently this cactus is present over around 100 square kms, with infestations varying from scattered plants to large clumps of plants. Although most plants are low growing, some reach 1.5 m high. This cactus has long thorns with detachable sheaths that discourage grazing close to plants and are a hazard to animals and vehicle tyres. The form of *Dactylopius tomentosus* present in N.S.W. does not appear to cause much damage to this species of *Cylindropuntia*. This plant is also naturalised near Menzies, Western Australia (*S. Januskiewiecz s.n.* – PERTH, NSW) and at a number of locations in South Australia (R. Chinnock pers. comm., Nov 2005). It is also reported to be naturalised in South Africa (Zimmerman pers. comm., Feb 2003).

Cylindropuntia spinosior (Engelm.) F.M.Knuth

Additional Record: Alongside and around old rubbish dump, Nebia Hill, west of Lightning Ridge, *J.R. Hosking 2403 & W.A. Cherry*, 25 Nov 2003 (ASU, BRI, CANB, MEL, NE, NSW, SD).

Notes: This cactus is also naturalised at Lightning Ridge where there were three large clumps and about 20 small clumps of plants in the area, with other plants scattered elsewhere over the Lightning Ridge opal fields. *Cylindropuntia spinosior* was also recorded from a property 50 km north of Longreach in Queensland in September 2006 (*B. Carlson s.n.* BRI).

CLUSIACEAE

Hypericum kouytchense H.Lév.

Notes: *Hypericum kouytchense* is more widespread in damp areas in the upper Blue Mountains than is indicated in Hosking et al. (2003). There is now a colour plate and more information available for this species in Robson (2004).

EUPHORBIACEAE

Chamaesyce ophthalmica (Pers.) D.G.Burch

Additional Record: Alongside New England Highway, between Uralla and Bendemeer, *J.R. Hosking 2708*, 8 Apr 2006 (BRI, CANB, MEL, NE, NSW).

Notes: This herb is now also found on the Northern Tablelands in N.S.W. Over 50 plants were found in gravel and soil on the edge and alongside the New England Highway at the above locality.

FABACEAE (FABOIDEAE)

Abrus precatorius L. subsp. ***africanus*** Verdc. [*Abrus precatorius* L. subsp. *precatorius sensu* Hosking et al. (2003).]

Crabs Eye

Description: Climber growing to 10 m high on supporting vegetation at Chinderah Golf Range. See Verdcourt (1970), and Stanley in Stanley & Ross (1983) as *A. precatorius*.

Region of Origin: Native of tropical Africa, Seychelles, Madagascar and Mauritius.

NSW Distribution / Habitats: North Coast. Coastal areas in various types of *Banksia* spp. and *Eucalyptus* spp. forest. Likely to naturalise in other high rainfall areas of coastal north-eastern New South Wales.

First Record: Chinderah Golf Range, 11 km south of Tweed Heads, *J.R. Hosking 2024 & R.L. Watson*, 14 Mar 2001 (CANB, MEL, NE, NSW).

Additional Records: Crabbes Creek, near Murwillumbah (NSW), *A.J. Beck s.n.*, 29 Jun 1981; roadside S of nursery, Hulls Road, S of Mooball, *N. Nicholson & A. McKinley*, Dec 1996 (NSW).

Notes: This species was incorrectly identified as subspecies *precatorius* in Hosking et al. (2003). Both subspecies have hairy pods but those of subspecies *africanus* are covered with low tubercles whereas those of subspecies *precatorius* are smooth. Subspecies *africanus* is also naturalised in south eastern Queensland (A. Bean pers. comm., January 2006) and in the Americas (Verdcourt 1970). Further information on this subspecies in northern N.S.W. and south eastern Queensland can be found in Hosking et al. (2003).

ROSACEAE (MALACOIDEAE)

Cotoneaster microphyllus Wall. [*Cotoneaster ?horizontalis sensu* Hosking et al. (2003).]

Small-leaf Cotoneaster

Description: Prostrate shrub. See Lu & Brach in Wu & Raven (2003).

Region of Origin: Native of China, Bhutan, India and Nepal.

NSW Distribution / Habitats: Central Tablelands. Known from a number of disturbed locations on sandstone-derived soils in mixed *Encalyptus* woodland.

First Record: Alongside drainage line in Harold Hodgsen Park, Katoomba, *J.R. Hosking 1840*, 23 Feb 2000 (AD, CANB, MEL, NE, NSW).

Additional Record: Amongst ruins of old building near corner of Narrow Neck Road and Farnells Road, Katoomba, *J.R. Hosking 2208*, 22 Apr 2002 (AD, CANB, MEL, NE, NSW).

Notes: This species was misidentified as *Cotoneaster ?horizontalis* in Hosking et al. (2003). The redetermination is based on Lu & Brach in Wu & Raven (2003). *Cotoneaster microphyllus* is actually a new record for N.S.W. as plants previously identified under this name (at NSW) are *Cotoneaster rotundifolius*. *Cotoneaster microphyllus* is also naturalised in New Zealand, the USA and the British Isles (Sykes and Given in Webb et al. 1988, Sigg in Bossard et al. 2000, Clement and Foster 1994).

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